IIASA COLLABORATIVE PROCEEDINGS SERIES

CP–82–S6

LIQUEFIED ENERGY GASES FACILITY SITING: INTERNATIONAL COMPARISONS

IIASA COLLABORATIVE PROCEEDINGS SERIES

CP–81–S1	LARGE-SCALE LINEAR PROGRAMMING Proceedings of an IIASA Workshop, 2–6 June 1980 G.B. Dantzig, M.A.H. Dempster, and M.J. Kallio, *Editors*
CP–81–S2	THE SHINKANSEN PROGRAM: Transportation, Railway, Environmental, Regional, and National Development Issues A. Straszak, *Editor*
CP–82–S1	HUMAN SETTLEMENT SYSTEMS: Spatial Patterns and Trends Selected Papers from an IIASA Conference on the Analysis of Human Settlement Systems T. Kawashima and P. Korcelli, *Editors*
CP–82–S2	RISK: A Seminar Series H. Kunreuther, *Editor*
CP–82–S3	THE OPERATION OF MULTIPLE RESERVOIR SYSTEMS Proceedings of an International Workshop, Jodłowy Dwor, Poland, 28 May–1 June 1979 Z. Kaczmarek and J. Kindler, *Editors*
CP–82–S4	NONPOINT NITRATE POLLUTION OF MUNICIPAL WATER SUPPLY SOURCES: Issues of Analysis and Control Proceedings of an IIASA Task Force Meeting, 10–12 February 1981 K.-H. Zwirnmann, *Editor*
CP–82–S5	MODELING AGRICULTURAL–ENVIRONMENTAL PROCESSES IN CROP PRODUCTION Proceedings of an IIASA Task Force Meeting, 2–4 June 1980 G. Golubev and I. Shvytov, *Editors*
CP–82–S6	LIQUEFIED ENERGY GASES FACILITY SITING: International Comparisons Howard Kunreuther, Joanne Linnerooth, and Rhonda Starnes, *Editors*

LIQUEFIED ENERGY GASES FACILITY SITING: INTERNATIONAL COMPARISONS

Howard Kunreuther, Joanne Linnerooth,
and Rhonda Starnes
Editors

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
Laxenburg, Austria
1982

NOTE

The International Institute for Applied Systems Analysis is a nongovernmental, multidisciplinary, international research institution whose goal is to bring together scientists from around the world to work on problems of common interest.

IIASA pursues this goal, not only by pursuing a research program at the Institute in collaboration with many other institutions, but also by holding a wide variety of scientific and technical meetings. Often the interest in these meetings extends beyond the concerns of the participants, and proceedings are issued. Carefully edited and reviewed proceedings occasionally appear in the International Series on Applied Systems Analysis (published by John Wiley and Sons Limited, Chichester, England); edited proceedings appear in the IIASA Proceedings Series (published by Pergamon Press Limited, Oxford, England) and elsewhere.

When relatively quick publication is desired, unedited and only lightly reviewed proceedings reproduced from manuscripts provided by the authors of the papers appear in this IIASA Collaborative Proceedings Series. Volumes in this series are available from the Institute at moderate cost.

International Standard Book Number 3-7045-0041-0

Volumes in the *IIASA Collaborative Proceedings Series* contain papers offered at IIASA professional meetings, and are designed to be issued promptly, with a minimum of editing and review.

The views or opinions expressed in this volume do not necessarily represent those of the Institute or the National Member Organizations that support it.

PREFACE

It is always pleasant to claim authorship of an idea that results in a successful product. It is doubly so when the innovation is an event that borders on the unique. In today's contentious world, a frequent occurrence in many countries and in many societies is the opposition of the individual to the general good.

The subject of the week long meeting, whose transcribed dialogues and debates are presented below, was just such instances deriving from technological development. In examining, in a comparative international context, the formal and informal procedures for resolving the problems of the siting of large industrial plants (in this case those treating liquefied energy gases), it became apparent that much would be learned from a structured confrontation of the views and ideas of the several interested parties in a research forum. If this could be achieved in a neutral, disinterested setting then the hypotheses of the IIASA research team could be tested before people who had taken active part in the social and administrative decision making.

Thus descriptive and interpretive case studies and models developed by the IIASA team after visits and interviews in the countries studied were used as the bases of the discussion and debate that took place in plenary sessions at Schloss Laxenburg. Civil servants from France, engineers and economists from the USSR, environmentalist leaders from the UK, the US, and the Netherlands, industrialists from the FRG, and local government officials, safety assessors, and social risk theorists from these countries together with IIASA staff may seem an unlikely, cumbersome, and even volatile mixture, but in the event it was exactly this amalgam of conflicting interest and opinion that produced a remarkably sharp and useful debate.

From it the team drew new insights, found new paths to explore, perceived new, simplified models of the procedures, formed a more cohesive "team view" of the world, and cemented useful and happy friendships with the hand picked participants.

The participants, each guided by interview and correspondence before the meeting into the development during the discussions of some particular aspect of the problem, gained further appreciation of the contrary and complementary views, recognized more clearly the universality of the problem and the particularity of some of their own national cases and found also that this academic interaction with real problems (which will lead to the open literature) held interest and hope for them. One participant hoped that "his soul would be saved" at this meeting, if policy implementation and analysis could be coupled. This short phrase covers much more than the above results indicate as achievements, but they are a move along the Damascene road leading technology to society.

I hope you will enjoy and profit from reading the edited proceedings presented here.

CRAIG SINCLAIR
Brussels
December 1981

ACKNOWLEDGMENTS

The Task Force Meeting reported in this volume was in many ways a special event at IIASA. Most of the participants, as well as IIASA scientists who chose to participate, agreed that a sense of excitement was generated that is seldom present at "scientific" meetings. These feelings can be attributed to the personalities and composition of the group, which included individuals representing all sides of the LEG siting debate from five countries. We would like to thank all of those individuals in the Task Force for their energy and active participation during the entire five days.

The person primarily responsible for selecting the participants for this meeting was Craig Sinclair who was assisted by David Bull, John Lathrop, and Joanne Linnerooth. Rhonda Starnes coordinated the arrangements for the Task Force Meeting and was assisted by Noël Blackwell. R. Starnes transcribed the many hours of discussion between the participants, and retyped and organized the volume for publication. Howard Kunreuther and Joanne Linnerooth edited these transcribed discussions. Meredith Golden was responsible for the organization of the sections and the introductory comments.

The Task Force Meeting was made possible through financial support from the Bundesministerium für Forschung und Technologie (BMFT), FRG, under contract no. 321/7591/RGB 8001. Werner Salz and Hans Seipel were responsible for the program of which this study was a part. We would also like to thank Alec Lee, Chairman of Management and Technology (MMT), Andrzej Wierzbicki, Chairman of Systems and Decision Sciences (SDS), Roger Levien, former Director of IIASA, and C.S. Holling, Director of IIASA, who have encouraged the Risk Group in its efforts.

HOWARD KUNREUTHER
JOANNE LINNEROOTH
RHONDA STARNES

CONTENTS

I. INTRODUCTION

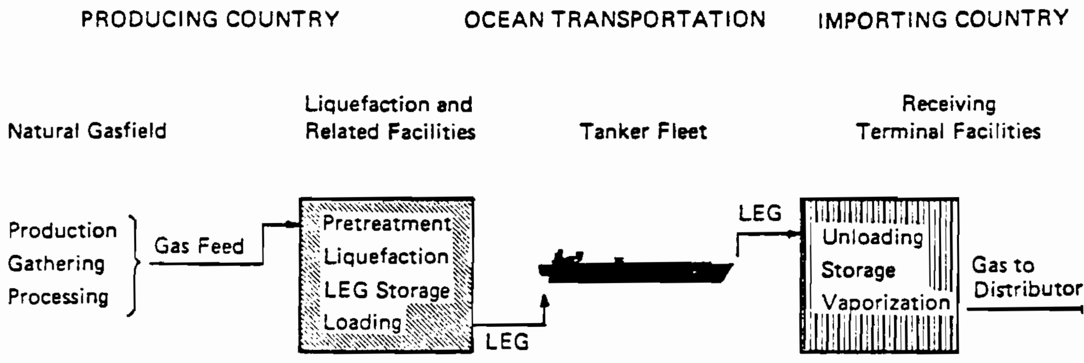
BACKGROUND

The siting of any large-scale energy or chemical facility poses decision problems which involve economic, environmental, and safety considerations as well as technological choices. The research project at IIASA is concerned with the systematic analysis of these decisionmaking processes with a view to improving their effectiveness and efficiency. As an international research organization of wholly neutral stance and established analytical expertise, IIASA is perhaps uniquely placed to explore socially acceptable solutions to problems involving technological risk.

IIASA's research on such decision processes and policies focuses on the siting of liquefied energy gas (LEG) facilities. The LEG study is appropriate for several reasons. First, LEG is already an important fuel for energy importing countries. Second, many of these countries and others are at various stages of planning LEG terminals. Third, LEG has received more scrutiny, in some respects, than many other hazardous substances. Thus, comparison of LEG siting procedures with other apparently similar problems could also be fruitful.

Liquefied energy gases (LEG) are comprised of two similar substances, liquefied natural gas (LNG) and liquefied petroleum gas (LPG). This potential source of energy requires a complicated technological process for transportation and storage that has the potential, albeit with low probability, of creating severe losses to populated areas. For purposes of transportation and storage these energy gases are liquefied to reduce their volume hundreds of times. For example, natural gas is chilled to -260^{o}F so that it becomes a liquid at about 1/600th of its volume at atmospheric pressure. Therefore, a tank of LNG has 600 times as much energy as an equal sized tank of natural gas. If these liquids spill from their containers, they vaporize and become highly flammable and explosive gases. A major spill in a densely populated area, whether by accident or sabotage, could have catastrophic consequences (US General Accounting Office 1978).

Liquefied energy gases are shipped in specially constructed tankers and received at a terminal where they undergo regasification; they are then distributed to different parts of the country, mostly by pipelines with the remainder carried by trucks or railcars. Figure 1 depicts the different elements of the system. The entire system (i.e., liquefaction



Adopted from Jensen Associates, Inc.

Figure 1. Major Segments of a Liquefied Energy Gases Project.

facility, the LEG tankers, the receiving terminal, and the regasification terminal) can cost more than $1 billion (in US dollars) to construct. For example, a large 500 million cubic feet per day project with four shifts would require a $2 billion expenditure ($1 billion for liquefaction/export facilities, \$600 million for the four shifts, and \$400 million for import/regasification facilities) (Office of Technology Assessment 1977).

The first LNG import facility was built in Cleveland, Ohio, US, in 1941, but after three years of service, the storage tanks ruptured, spilling LNG on adjacent streets and sewers. The liquid evaporated, the gas ignited and exploded resulting in 120 deaths, 300 injuries and approximately \$7 million in property damage (Davis 1979). This accident set back development for approximately two decades. Interest in utilizing this technology, however, has accelerated in the last ten years as concern with alternative sources of energy has attracted attention.

The siting of large LEG handling facilities poses difficult technical, economic, and political problems. Proposed and existing terminals are large-scale operations located in coastal zones and near major shipping channels, some in major harbors or near population centers. They require considerable amounts of land and capital, and represent a large concentration of energy at a single site. Since the technology, like many others, cannot be proven absolutely safe, there exists a risk to the surrounding population. The location of a terminal, thus, can be a major factor in its safety. The magnitude and extent of any resulting damage from an LNG/LPG spill can depend on the proximity of the terminal and storage sites to other industrial and residential areas. Since a site remote from a populated, industrial area is usually costly in terms of both higher gas prices to the consumer and environmental degradation of the area, the choice of site poses the problem of weighing benefits versus risks.

Such tradeoffs, by no means unique to the siting of LEG facilities, are currently receiving a great deal of attention. An area of research, usually known as risk assessment, has evolved to answer questions of "what is an acceptable risk?" or "how safe is safe enough?" A standard approach to such questions is to estimate the risks, in probability terms, and to determine the acceptability of these probabilities. In this way, the debate has often narrowed to inquiring whether, for example, a 10^{-6} risk of death resulting from the introduction of a technology is acceptable or not acceptable.*

*It has been suggested that, where appropriate, this question be framed in terms of (a) the background risk—is the population routinely exposed to this risk from natural sources?, (b) revealed preferences—does the population accept other hazards posing a 10^{-6} risk of death?, or (c) expressed preferences--if questioned, would those affected be willing to accept this risk given the benefits of the technology?

It has become increasingly clear that this approach to the problem is helpful, indeed necessary but not sufficient, in determining the acceptability of a large-scale technology. Many of the concerns germane to the debate cannot be addressed by a risk analysis alone. Indeed, the attention given to the safety issue, in some cases, may be reflecting deeper and more vague concerns over the future of a high-technology society. These concerns might be articulated in many ways, including an expressed distrust of the "expert" calculations or an unwillingness to accept the imposition of any probability of an event judged to be catastrophic.

In addition, the issues may be one of *who* bears the risk and *who* receives the benefits. Nearly every choice affecting public safety will yield results desirable for some groups and undesirable for others. Ultimately, the query "how safe is safe enough?" is a political question, to be decided in the arena of political choice. No totally accepted technique exists for separating completely the fact and value judgments required.

It is this reasoning that has led the IIASA Risk Management Group to choose an institutional approach to the analysis of problems dealing with technological risk. Since the question whether an LEG facility poses an acceptable risk to the public, or whether it should be sited at a more remote site at higher cost, is finally decided on political grounds, it is important to understand the participants, institutions and processes comprising the decision-making forum.

The most acceptable risk is that associated with the most acceptable option, and this choice depends on the problem definition. So, as a start, it is necessary to identify exactly what it is that is being decided. Is the choice simply where to locate an LEG import or export facility bearing in mind the economic, environmental and safety factors? Or is the choice rather one of energy policy, a question of whether the proposed project is consistent with long-term energy goals taking into account conservation measures, development of alternative energy sources, public safety and economic growth? The breadth of the decision, to a large extent, defines the processes which will evolve to handle it and vice versa.

Turning to the decision process, there are several levels at which the IIASA group investigations advance. On a descriptive level, we ask who are the participants and interested parties, and how do their preferences weigh in the final choice of the site? Who makes this final choice: the national, regional or local authorities? How is this choice made? We investigate both the formal and informal channels by which the views and demands of these parties are communicated.

On a more analytical level, we identify the crucial decision points and ask why these decisions were taken. What factors had the most weight in forcing the choice? What were the motivations of the parties, and what were their institutional constraints? Other important criteria for analyzing the institutional procedures are the types of information being fed into the process and the channels open to the information flow. Who collects what information, when? Who has access to this information? How is it biased by the institutions or groups who manage it? A related question is that of how the choice of a sovereign agency, with its mix of professionals, can influence the decision?

On yet another level, we try to evaluate this process. How legitimate are the procedures as viewed by the parties involved? If there is a forum for public debate, how effective can this forum be in light of the complexity of the issues? Can the problem be openly discussed in all its aspects? Most importantly, we ask how the public perceives the procedures in terms of their openness and fairness.

Of special interest to the IIASA work is the role that formal risk analyses play in the process. Does a detailed analysis of the risks promote reasoned debate by allowing the protagonists to identify points of disagreement, or does a risk analysis inhibit debate by the use of sophisticated, and often difficult to understand, methodologies?

It is also important to investigate the costs of the proceedings. An open process is expensive in terms of the time lost to participants, the hearing costs and the volumes of reports generated by the many interest groups. One is tempted to add delays to this list; however, the lack of an open process may itself generate strong opposition and delay the process even more. Indeed, even the role of delay is ambiguous. Whether the time lost in siting a large-scale facility is indeed a cost depends on the immediacy of the need, the alternatives, and the contemporaneous desirability of the project. Delays allow time to reflect as well as time to discover new alternatives.

On a final level, it is important to ask if the process can be improved. Are the procedures leading to the selection of a site for an LEG terminal appropriate in terms, *inter alia*, of their accessibility to the public, their potential for early consideration of alternatives, the avoidance of unnecessary delays, and a total increase in national welfare?

The intent of this Task Force Meeting was to bring together people involved in the siting of LEG facilities, to explore these issues in the context of five selected countries: the Federal Republic of Germany, France, the Netherlands, the United Kingdom, and the United States. The participants were selected to represent all levels of involvement, including local citizen groups, national environmental organizations, governmental regulatory agencies, industry, as well as the analysts involved in the siting problem. The views expressed and the problems raised during this meeting have guided the work of the IIASA Risk Group in their comparative study of siting LEG facilities. A major focus of this work is on the role of experts and analyses in the siting processes given current limitations on human knowledge and on the understanding of risks from handling liquid energy gas.

In this volume are papers that were prepared for the Task Force Meeting. The majority of these papers were presented to the participants, with subsequent discussions. Edited versions of these discussions can be found following the appropriate presentation. In three instances, the actual presentations made by certain participants were deemed worthy of also being included in this volume, as they differed from the prepared paper.

REFERENCES

Davis, L.N. 1979. *Frozen Fire*. Friends of the Earth.

Office of Technology Assessment. 1977. *Transportation of Liquefied Natural Gas*. Washington, DC: Office of Technology Assessment.

US General Accounting Office. 1978. "Need to Improve Regulatory Review Process for Liquefied Natural Gas Imports," Report to the Congress, ID-78-17, Washington, DC.

INTRODUCTORY STATEMENTS

CHAIRMAN CRAIG SINCLAIR: This afternoon we want to discuss the problem of the use of analysis and its limitations. We will be talking about particular sites in the following couple of days. The final morning has been left open with the agenda to be decided during the week. Before moving to the IIASA presentations I would like each person to introduce him or herself and briefly indicate what they hope to see come out of this meeting.

Before beginning, two administrative remarks. One is that we are funded by the German Federal Ministry for Research and Technology (Bundesministerium für Forschung und Technologie--BMFT) and Dr. Werner Salz is representing that institute here. Secondly, we plan to publish the proceedings. We certainly will not publish any of the papers or the discussions which are being taped at the moment, without your express permission. We hope that the discussion can be Chatham house rules (as the British say) which means "Safe from quotation without permission of the author."

PARTICIPANTS

WILLIAM AHERN (USA): I work for a special agency in California (the California Coastal Commission) which is supposed to protect Malibu, Big Sur, and other areas along the California coast from developments such as Liquefied Natural Gas terminals. I am here, because, as you know, we like to experiment in California with Roller Skates, disco dancing, surfing and other such things. We also experiment with energy facility siting processes; I would like to know how it's done in other countries.

ANTHONY BARRELL (UK): I am a chemical engineer administrator from the Health and Safety Executive in the UK. This is the regulatory agency responsible for Health and Safety Legislation in Britain. During this week I look forward to listening to what everybody else has to say and to learn from their experiences. Also, I hope to make some contacts for the future.

NIALL CAMPBELL (SCOTLAND/UK): I work in the Scottish Development Department which is a central government department involved with one of the case studies, Mossmorran. I am interested in finding out the procedures and approaches which are used in other countries facing a similar type of problem.

C.D.J. CIERAAD (NETHERLANDS): I am with the same institute as Jaap Schwarz, but in a different department, the Energy Studies Department. As a decision analyst I have been working in the risk and energy policy areas. I am here because I am very much interested in improving my insights into political decision making processes, and better understanding the role analyses can play in these processes.

LOUIS CLARENBURG (NETHERLANDS): I am the Administrator for Environmental Care of the Rijnmond Authority, a small territory around Rotterdam which has an important harbor. As for my background, I refer to myself as a professional layman. What I would like to get out of this meeting is a better appreciation of the risk analysis of the LEG chain, of which siting is only a small part.

PHILIPPE CRUCHON (FRANCE): I am working in the gas department of the french Ministere de l'industrie.

NORBERT DALL (USA): My professional training is in political analysis. For the past four years I have spent much of my time giving Bill Ahern and sometimes Randy Deutsch a bad time as project manager of the Sierra Club's intervention in the Point Conception LNG project in California. The Sierra Club is a major environmental organization of 200,000 members in North America. I am now the executive director of the nonprofit Alliance for Coastal Management, a more broadly based organization involving business, labor, and some environmentalists, that is reviewing and seeking to improve California's coastal management program. My interest in coming here is to increase my comparative understanding of major industrial facility planning, decision-making, and societal responses.

RANDOLPH DEUTSCH (USA): I am an attorney with the California Public Utilities Commission. I have represented the commission and the State of California on LNG projects for the past five years. I am here somewhat as a devil's advocate. I have a limited scientific background and I will horrify you by telling how we misuse, and how little we do use analysis. From this meeting I hope to gain knowledge of ways in which other countries use the scientific approaches being developed.

RALPH KEENEY (USA): I was at IIASA from 1973-75, and I now work on decision and risk analyses and siting problems for Woodward-Clyde Consultants, a consulting firm in San Francisco. I would like to outline in this meeting an approach to siting that has a lot of advantages, but I will also indicate what it cannot do. I hope to gain a lot of specific insights from you, who have much more expertise on specific problems than I do, to help improve the role analysis might play.

SALLY MACGILL (UK): I am a lecturer in Geography at Leeds University. I have undertaken a case study of the Mossmorran and Braefoot Bay Facility. I am interested in finding out how decisions for similar facilities elsewhere are taken.

YU. MAKSIMOV (USSR): I work with the economics department at the Siberian Institute for Economics and Organization of Industry. I want to present information on economic programs for improving production in gas pipeline and other transportation methods.

DICK MEHTA (UK): Amongst other things, I am chairman of the Citizens Action Group representing a community that may well be affected by the Mossmorran development. In that sense, my perception of this problem is somewhat different from that of others here, because I am at the receiving end of the risk takers. At the same time, I think I can show that our reaction to the Mossmorran decision has been far from a purely emotional one, and that we as a community have been able to provide a fair amount of input into the safety debate on Mossmorran. And since Mossmorran has been chosen as a case study, I hope to demonstrate that decisions of this sort are being taken, even in supposedly technologically advanced countries, in a purely haphazard and bizarre way without much conception of the problems involved. I hope during the course of the meeting to be able, as a non-scientist, to bring you scientists down to earth from time to to time, from the cloud cuckoo land of risk analysis and systems analysis. I hope by the end of this meeting we will have an admission by the scientists that there are problems to which they do not have the answers and that, therefore, sensible siting criteria ought to be applied when planning for major developments.

ROBERT NORTON (USA): I am from Distrigas in Boston, Massachusetts. I hope to point out that perhaps the siting of LEG facilities with no recourse to systems analysis, in fact, has not worked out all that badly. Yet, within the framework that does exist, I think there are definitely applications for systems analysis with existing facilities.

YU. OSEREDKO (USSR): I am chief engineer for the All-Union Designing Institute for Gas Industry in Kiev, and I want to present for your information, details of the construction of an experimental Russian complex for LNG in Yerevan, Armenia.

HARRY OTWAY (USA, UK, ITALY): I am from the Joint Research Centre of the European Communities in Italy. I have been involved in both technical and social risk analyses for the past 15 years. Now I am starting to see that analysis is essentially irrelevant to the process of policy formation. I think that in practice there is not much connection between analysis and policy. Perhaps this meeting will convince me otherwise.

JERRY RAVETZ (UK): I teach the History and Philosophy of Science at the University of Leeds and I have been interested in science (taken in a general sense) as a social activity. Some years ago, I worked with the Council for Science and Society in London, and I have continued to work on the acceptability of risk. I then got the feeling that risk is one focal problem for our society, and I have been studying the philosophy of risk and risk management ever since. My interest in a meeting like this is to see how scientific knowledge or technical expertise are applied in ways which are relatively new for sociologists of science. I think we have new conceptions of scientific knowledge, new conceptions of the scientific role, which I believe quite urgently need sorting out. So I have come to this meeting, partly to reflect in your presence on risk problems and partly to reflect on the way on which scientific knowledge is deployed. I hope to learn as much as I can.

LUCAS REIJNDERS (NETHERLANDS): I was trained as a molecular biologist, and more recently moved into interdisciplinary studies related to environmental aspects of technology. Currently I am working with a non-governmental organization in Holland. My main interest is in the structuring of decision problems in relation to risky activities, with special interest in the descriptive/prescriptive point of view.

WERNER SALZ (FRG): I am from the Ministry for Research and Technology in Bonn where I am working in a group concerned with safety engineering. This group is part of the energy division. From this session I expect to gain an international perspective on how decisions for energy processes are made, and what significant differences exist between these countries.

JAAP SCHWARZ (NETHERLANDS): I am working at the Policy Analysis Department at TNO, the organization for applied scientific research. I have been working in the field of risk for about 6 years. I am very much interested in the feedback processes from society to technological development. I hope we will come a little bit further in this meeting on how we define these feedback processes.

ROBERT VINCENT (FRANCE): I work for Gaz de France, where I have been focusing on the LEG area for more than 15 years. I am presently employed in the department which deals with LPG supplies, LNG terminal siting, and operations. With the exception of Mr. Norton from Distrigas, I feel I am the only one in this assembly who has practical experience with LNG terminals in operation. I can't define precisely what I am interested in in the next few days; I can only say that I am here as an observer.

SINCLAIR: We can qualify David Bull as an Industry Man and we have coming on Thursday, Dr. Schwier from Ruhrgas, so Dr. Vincent won't be the only industry man here.

IIASA STAFF MEMBERS

HERMANN ATZ (AUSTRIA): I have just started to work with the LNG project at IIASA. My training is in physics and more recently in political sciences. I have two interests in the task force meeting. First, I hope to gain more general insights into the problems of LEG siting, and second, I hope to get information on the political processes in the context of specific case studies.

DAVID BULL (UK, SWITZERLAND): During the last eight years I built up a rather large research group working on industrial hazards. One of my better customers was the LNG and LPG interests. I have been concerned with the hazards of explosion and fire, with the quantification of their effects, and with the fundamental mechanisms by which they can be appraised. I am concerned, of course, by the use which is made of this information and in particular by the way in which the uncertainty attached to the physical processes is handled in some of the siting process schemes. Over the last year I have been working with the IIASA team, but this summer moved to Zurich.

HOWARD KUNREUTHER (USA): I am here at IIASA on sabbatical from the Department of Decision Sciences at the Wharton School, University of Pennsylvania. Since coming here in mid-July, I have been particularly interested in the LEG project, because it represents a very interesting prototype for the kind of work that is needed in understanding a wide variety of different problems involving societal risk management. Later this morning I will suggest ways that one may begin to integrate some of the descriptive aspects of the problem with the prescriptive side. I hope to gain from all of you insights into how this applies to LEG.

JOHN LATHROP (USA): I am a scientist at IIASA, part of the research team that organized this meeting. My motivation to go into the line of research we are pursuing here grew out of my attempts to get risk evaluations performed and get them incorporated into political decision processes. After much effort I found myself saying: "Hey, Nobody is listening to me." I foolishly thought that perhaps if I shouted a little louder or added one more dimension to my evaluation, maybe I would be heard. Well, nobody has listened to me yet, a fact we can blame on any number of things. But in the course of this week I would like to gain some understanding of how we can promote communication between people like me and the people who really make the decisions.

JOANNE LINNEROOTH (USA): I am a member of the IIASA team, where I have been working for several years in the area of risk analysis. I have been working with Harry Otway, and I'm afraid some of his cynicism has worn off on me. In fact, this is one of the reasons that I am pleased with the institutional approach to the questions of acceptability and the safety of technological risk that our group is taking. We are trying to look at these questions within the framework of the political decision process. That is why you are all here, and I hope to learn from each of you something about these processes and how formal analyses can be of use to you.

MICHIEL SCHWARZ (NETHERLANDS): I have been working with the IIASA team on policy analysis of LNG siting decisions, particularly in the Netherlands. I had limited experience before in risk studies, but I have been involved in policy analyses, especially on science and technology. I am normally working with the Science Policy Research unit at the University of Sussex in the UK, where my main interest is government policy on large-scale technological projects. Obviously LNG and LEG siting decisions are relevant in this context.

MARK SHAREFKIN (USA): My current affiliation is with Resources for the Future in Washington, D.C. I am temporarily at the Department of Economics at the University of Stockholm (the Industrial Institute for Economics Research). I am a mathematician by training, and for the last ten years I have worked a lot with the U.S. Congress. Currently, and for the next three or four years, I will be involved with a project which is aimed at contributing to the design and implementation of the toxic substances control act in the United States. I have, for obvious reasons, a keen interest in some parallel cases so we can learn from them.

MICHAEL THOMPSON (UK): I am a social anthropologist here at IIASA for a year, with the Systems Decision Sciences area. I would approach risk rather in the way that an art historian approaches art. I am interested in the aesthetics of risk, in styles of risk handling. What would interest me in this meeting would be to see which different styles are being advocated or pursued. I put on this little Tibetan badge this morning because I thought there might be one style not very well represented here--the Lamaist Buddhist style of risk handling. When the Dalai Lama was in Berkeley last year, somebody there asked him about technological risk, about all these things that are going to happen to us, and he replied that "if its soluble, no problem. If it's not soluble, no problem."

II. CONCEPTUAL ISSUES AND SELECTED LEG CASE STUDIES

The papers presented in this section describe specific case studies as they relate to IIASA's research on LEG siting processes and decisions. They create a framework for organizing the issues and motivating the debate. The aspects discussed include: the alternatives considered; the decisions faced; the participants involved in and groups affected by those decisions; and, the objectives and tradeoffs of those participants. The problem structure attempts to represent the ways interested parties participate and interact in various types of hearings, court proceedings, legislation, media, polls, political processes, etc. Other key foci include the roles that technical, economic, and risk analyses play in the overall process.

The first paper, by Howard Kunreuther, is concerned with "Societal Decision Making for Low Probability Events: Descriptive and Prescriptive Aspects." Michiel Schwarz has done a short informative case study on LNG siting in the Netherlands. The paper by S.M. Macgill provides background information to the decision to allow the construction of a large-scale LEG facility at Mossmorran and Braefoot Bay in Fife, Scotland. Finally, Joanne Linnerooth has done a short history of the siting of the California LNG terminal in the US.

SOCIETAL DECISION MAKING FOR LOW PROBABILITY EVENTS: DESCRIPTIVE AND PRESCRIPTIVE ASPECTS

Howard Kunreuther
IIASA

I. INTRODUCTION*

Society has become increasingly concerned with the appropriate procedures for evaluating projects which promise to yield long-run benefits, but also create potentially catastrophic consequences. Recent examples of such problems are the siting of energy facilities such as nuclear power plants or liquefied natural gas (LNG) terminals.

This paper has two principal purposes. Utilizing recent theoretical and empirical contributions to the literature on choice under uncertainty, it proposes a descriptive model as to how such decisions are reached in the United States. On the basis of this descriptive model,

*This paper, prepared for the IIASA Task Force Meeting on Liquefied Energy Gases, reflects many helpful discussions with IIASA colleagues—John Lathrop, Joanne Linnerooth, Michiel Schwarz, Craig Sinclair, and Michael Thompson. Randolph Deutsch, John Lathrop and Ralph Keeney provided helpful comments on an earlier draft of this paper.

suggestions are made for improving the process. The paper thus attempts to integrate descriptive and prescriptive components for analyzing these societal problems.

Section II sketches the elements of a descriptive model of the societal decisionmaking process. This model describes the process of choice by individual parties, each of whom have specific goals and objectives, limited information which are guided by these objectives, and scarce computational resources. It is thus in the spirit of what Simon (1978) terms procedural rationality. The model extends these notions to the case where there are several interested parties who must interact and arrive at a solution for a particular problem. Hence there is an additional layer of complexity imposed on the structure—the interaction between stakeholders who may have different objectives and hence differential information bases.

Section III illustrates the descriptive model with empirical evidence from the LNG siting decision process which has been studied extensively (see Ahern 1980a; Deutsch 1980; Lathrop 1980; and Linnerooth 1980). The paper also utilizes material from studies by Davis (1979) and the Office of Technology Assessment (1977) on the nature of the LNG controversy in the United States. Section IV indicates how we might improve the current situation by recognizing that the descriptive process is based on a number of institutional and legal constraints which may be difficult to change. In developing these prescriptive measures, I will build on the concepts of decision analysis as applied to siting decisions (Keeney 1980), the concepts of assumptional analysis developed by Mitroff, Emshoff and Kilman (1979) as well as policy analysis. Section V provides a brief set of conclusions.

II. DESCRIPTIVE MODEL OF SOCIETAL DECISIONMAKING

Relevant Concepts

In contrast to most textbooks analyses of decisionmaking under uncertainty, where there is a well specified set of probabilities of certain events occurring and potential gains or losses from them, the problems discussed in this paper have grave uncertainties about them. For one thing, there has not been a long history with which to build a statistical database. The technologies are relatively new and in many cases past experience provides us with limited guidance as to the chances of severe accidents occurring. In a similar vein one has to speculate as to what the losses might be should a particular catastrophic event occur in a given location. These two elements of uncertainty represent a challenge for both risk analysis and decisionmaking

On the analysis side, there is a need to systematically estimate probabilities and consequences from both past data and judgmental studies. There is an extensive literature from controlled laboratory experiments over the past decade which have uncovered a set of biases and heuristics that individuals utilize in dealing with low probability events (Fischhoff, et al. in press; Tversky and Kahneman 1974). Other studies have suggested that the context in which a problem is framed plays a key role in how people make their decisions (Hershey, et al. 1980; Tversky and Kahneman in press). These findings, partly due to computational limitations on the part of individuals, present a challenge to the analyst who would like to improve the decisionmaking process. An attempt in this direction has been taken by Fairley (1977) who provides a detailed set of guidelines for estimating "small" accident probabilities based on a consideration of catastrophic risk analyses for LNG marine transportation. His motivation for suggesting systematic analyses, is that there is a great danger that many sources of an accident will otherwise be omitted. In addition, there are numerous opportunities for bias with respect to judgmental estimates of accident probabilities when there is *not* a long history of past events. Similar reasoning would apply to the analysis of losses from a given accident, such as a major breach of an LNG tank.

On the decisionmaking side, the lack of a detailed database implies that different stakeholders or interested parties will have different estimates of the probabilities and the losses that guide their own judgments. I will look at the process in terms of a scenario involving a number of different decisions, which taken together resolve a particular problem. Some of the decisions may be solved in parallel by different parties; others may be dealt with sequentially.

The *decentralized and sequential nature of the process* are key concepts which guide the descriptive analysis. March (1978) characterizes this process as one of limited rationality, whereby individuals and groups simplify a large problem into smaller pieces because of the difficulties they have in considering all alternatives and all information. Support for these concepts at the level of governmental, firm and consumer decisionmaking comes from several quarters. Lindblom (1959, 1965) emphasizes the incrementalism in decisions made by bureaucracies where there is a tendency for government agencies to "muddle through" by making small changes from the status quo rather than attempting to structure and solve a larger problem. Cyert and March (1963), in their classic study of the behavioral theory of the firm, provide empirical evidence on this behavior by showing how organizations decentralize decisions and attend to different goals and objectives at different times. Bettmann (1979) integrates findings from a number of studies and suggests that the consumer simplifies the decision making process by decompartmentalizing the problem, utilizing limited search, and behaving sequentially with appropriate feedback loops.

Another important concept, which also relates to the uncertainty of information on probabilities and losses, is the *importance of exogenous events* in influencing the decision process. Random events, such as disasters, play a critical role in triggering specific actions to "prevent" future crises. The small data base for judging the frequency of low probability events, coupled with systematic biases of individuals in dealing with concepts of chance and uncertainty, increases the importance of a salient event in the decisionmaking process. Tversky and Kahneman (1973) describe this phenomenon under the heading of availability, whereby one judges the frequency of a event by the ease with which one can retrieve it from memory. The importance of past experience in influencing consumer decisions to purchase insurance against low probability events (Kunreuther, et al. 1978) reflects this characteristic of human behavior. In a similar spirit, March and Olsen (1976) suggest that random events and their timing play a critical role in many organizational decisions because of the ambiguity of many situations and the limited attention that can be given to any particular problem by the interested parties unless it is perceived as being critical. They provide empirical evidence to support their theory using empirical studies of organizations in Denmark, Norway, and the United States.

With respect to legislative decisionmaking, Walker (1977) suggests the importance of graphically and easily understood evidence of trouble as an important factor in setting the discretionary agenda of the U.S. Congress or a government agency. He also suggests that the political appeal of dealing with a specific problem is increased if it has an impact on large numbers of people. To support these points, Walker presents empirical evidence on the passage of safety legislation in the U.S. Numerous examples of this process are also provided by Lawless (1977) through a series of case histories of problems involving the impact of technology on society. He points out that frequently:

> new information of an "alarming" nature is announced and is given rapid and widespread visibility by means of modern mass communications media. Almost overnight the case can become a subject of discussion and concern to much of the populace, and generate strong pressures to evaluate and remedy the problem as rapidly as possible. (p.16)

In the case of decisions such as the siting of facilities, random events such as an LNG explosion or an oil spill may be sufficiently graphic and affect enough people to cause a reversal of earlier decisions, inject other alternatives into the process and change the relative strength of parties interested in the decision outcome. The mass media may play critical role in focusing on these specific events and in many cases exaggerating their importance.

Model Formulation

The concepts discussed above have motivated the following descriptive model of the societal decisionmaking process. A scenario consists of a sequence of decisions $\{D_1, \ldots, D_n\}$, which have to be made by different interested parties. In focusing on any particular problem, it is necessary to specify what the n different decisions are that comprise a particular scenario. For example, Ahern (1980a) and Linnerooth (1980) have constructed a detailed flow diagram of the different decision points with respect to the siting of the LNG terminal in California. Here the process begins with the Western LNG Terminal Company filing an application with the Federal Power Commission (FPC) for terminal facilities. It continues through a set of interactions between federal, state and local governmental agencies, as consumer groups and the Western LNG Terminal. In the case of the nuclear power plant licensing decision Jackson and Kunreuther (1980) have constructed a scenario which emphasizes the decentralized nature of decisions by separate divisions of the Nuclear Regulatory Commission. The performance of a plant under a series of predetermined accident scenarios is a basis for the final decision as to whether or not to approve a power plant.

These two examples suggest that, although one can look at a particular decision in isolation, it will be integrated with other actions by being dependent on earlier decisions (e.g., the LNG siting decision) or by being integrated at a later stage with other decisions which are made independently of it (e.g., the licensing of nuclear power plants).

Consider a particular decision, D_j, (e.g., the safety of an LNG terminal) which is part of a overall scenario. Figure 1 depicts the relevant aspects of the process. At any time period, t, there are a set of *exogenous factors* which limit the set of alternatives for consideration. For example, a disaster may trigger specific legislation which provides restrictions on where an LNG terminal can be located. The *input phase* of the process involves the relationship between the set of alternatives and the relevant stakeholders and attributes or measurable impacts (e.g., number of lives lost from an LNG explosion) which are considered important by at least one of the interested parties. There is a clear interaction between stakeholders and attributes: as one changes the composition of stakeholders then the relative importance of attributes also changes. For example, if public interest groups have a voice in the site selection process then the safety factor may be treated as much more relevant than if these parties did not have an input into the final decision. Similarly if certain attributes are specifically introduced into the picture by one of the interested parties, then this may cause other groups to play a more active role in the process. For example, if the federal government suggests the critical importance of safety factors as part of the siting decision, then concerned citizens may unite to prevent their community from being chosen as a site.

Each interested party is likely to have a different set of attributes that they consider to be important to the particular problem. Furthermore, there is no guarantee that two interested parties who focus on the same attribute will measure it in the same manner. For example, public interest groups concerned with the safety of potential sites may have a different estimate of the number of lives lost from a severe accident then the gas companies or the consortium proposing the project. Over time the nature and importance of these attributes may also change due to exogenous factors and a new set of alternatives.

When it comes to the *analysis phase*, stakeholders are likely to evaluate different alternatives by looking for satisfactory options rather than trying to find an optimal solution (Cyert and March 1963). For each decision D_j there may be some level of a particular attribute that is deemed satisfactory, but whose value may differ between interested parties. For example, public interest groups may view the acceptable level of risk for a large accident to be somewhat lower than the gas company proposing the project. As a result these two interested parties may have differing views on the acceptability of alternative sites. When such conflicts occur, they may cause long delays in reaching a final decision because there are no clear responsibilities between different agencies. Eventually they may be resolved through some form of consensus by the interested parties, by court rulings or by governmental bodies with specific legislative powers to settle the controversy. For some problems no resolution may take place and the status quo is maintained.

Looking at Figure 1, a critical question is the nature of stakeholder conflicts. If there is a call for more information, this is treated in the figure as being equivalent to postponing action until the next period. In period t+1, a set of random events may occur that substantially change the situation. The breach of a gas tank or the discovery of an earthquake fault may reveal certain features of facilities or sites which may make

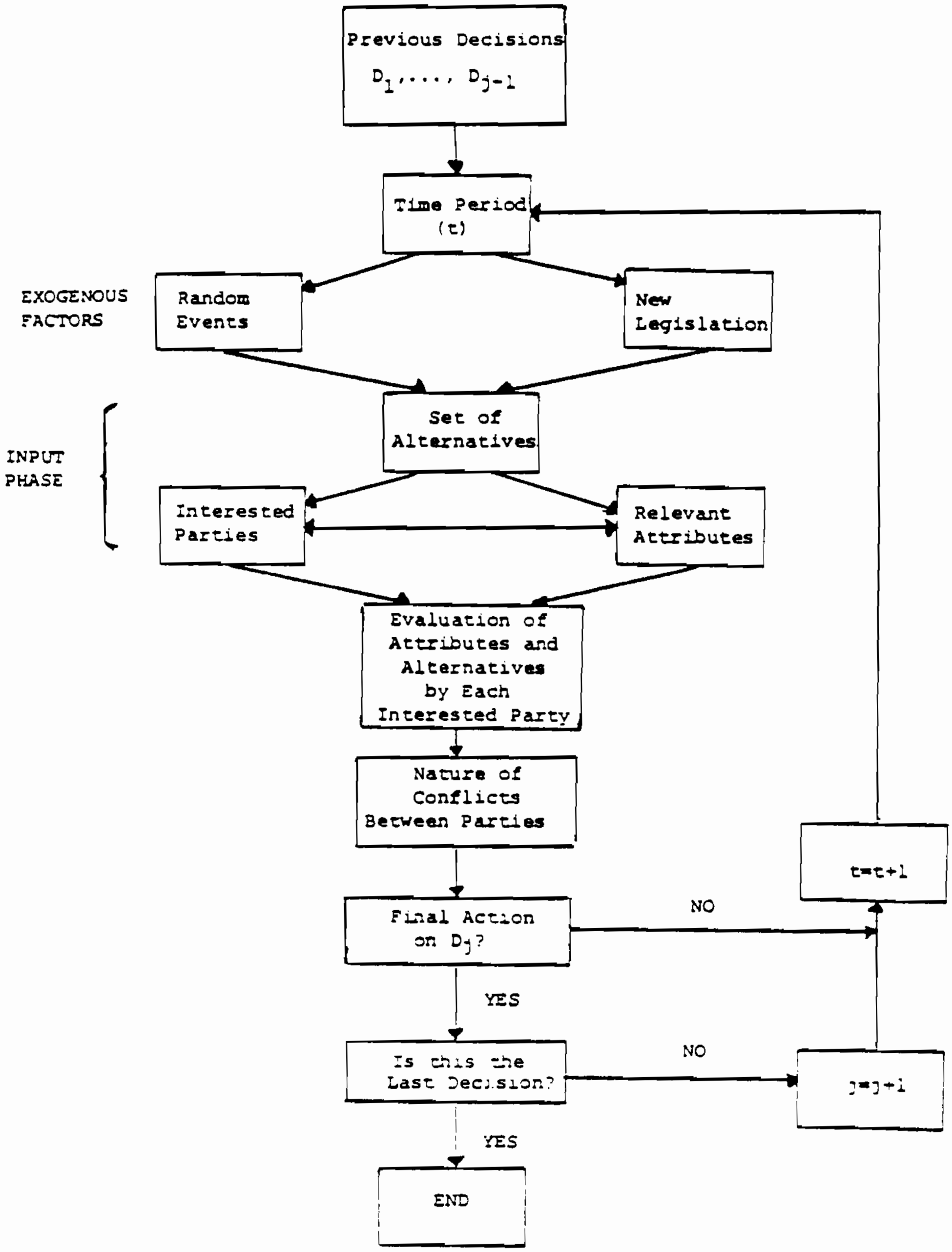


Figure 1. Descriptive Model of Choice.

them unacceptable. These random events may change the relative importance of different stakeholders and attributes. In addition, the events and the public's reaction to them may trigger new legislation which deem certain previously satisfactory alternatives unacceptable and force a re-evaluation of earlier decisions $\{D_1, \ldots, D_{j-1}\}$.

To summarize, there are a set of decisions which have to be made over time as part of a scenario for a particular problem. There are laws and regulations which guide the acceptability of specific alternatives and there are different stakeholders involved in the process. Because of the uncertainty of information regarding probability and potential impacts of catastrophic events, interested parties with different goals and objectives and with limited computational capacities may have different estimates of the risks associated with specific actions (e.g., the safety of an LNG terminal at a particular location). Furthermore, random events in period t can have a major impact on the decisionmaking process by triggering new legislation which change the set of alternatives, relevant stakeholders and attributes for consideration. Conflicts between relevant stakeholders can lead to lengthy delays with respect to taking final action.

III. THE LNG SITING DECISION IN THE UNITED STATES

The above descriptive model, outlined in Figure 1, will be illustrated by analyzing the decision process associated with siting an LNG terminal in the US. I will first describe the nature of the problem, delineate the relevant stakeholders and attributes perceived to be important and then discuss the role of exogenous factors in the decision process.

Nature of the Problem

Liquefied natural gas (LNG) is a potential source of energy which requires a fairly complicated technological process that has the potential, albeit with very low probability, of creating severe losses. To import LNG the gas has to be converted to liquid form at about 1/600 the volume. It is shipped in specially constructed tankers and received at a terminal where it undergoes regasification and is then distributed. The entire system (i.e., the liquefication facility, the LNG tanker and the receiving terminal and regasification facility) can cost more than $1 billion to construct (Office of Technology Assessment 1977). The siting problem of interest consists of two principal decisions: whether proposed facilities for regasifying and shipping LNG is in the national interest (D_1), and if so, whether the proposed site is considered safe enough (D_2).

Interested Parties and Relevant Attributes

According to the descriptive model, there will be a set of interested parties associated with each of these decisions. Some of these stakeholders will be specified by law (e.g., government agencies), others will play a role because of specific concerns with the hazard (e.g., public interest groups) and others because of their economic interest in the project (e.g., gas companies). In the case of D_1, there are two principal stakeholders, each of whom considers different attributes as important to their decision process. The *gas company* or the consortium proposing the project conducts the site selection process by considering such attributes as accessibility by large tankers, availability of the market, i.e., proximity of an existing pipeline network, cost of land acquisition, availability of skilled labor supply, and in some cases, land use characteristics and environmental factors (OTA 1977). The other interested party is the *Department of Energy*, which has to determine whether an individual LNG import project is in the public interest and should be allowed.[1] If the project involves foreign imports, then the responsibility resides with the Economic Regulatory Agency (ERA); if the terminal involves interstate commerce then the Federal Energy Regulatory Commission (FERC) is involved.

According to the National Gas Act of 1973 which governs all imported natural gas cases, the Department of Energy (DOE) cannot approve any project which is not consistent with the public interest. Among the principal attributes that DOE is supposed to consider in making this judgment are factors such as the security of supply, the proposed LNG price in relation to the price of alternative supplies, impact of the price schedule on conservation of energy, and whether the proposed site meets safety and environmental requirements as stated in any national guidelines (DOE/ERA 1977).

The current decision process is an attempt to reduce conflicts between the parties: the gas company or consortium proposes a site which they consider to be safe and in the national interest. Relevant agencies of the Department of Energy then evaluate this site and issue an

[1] Prior to 1977 this responsibility resided with the Federal Power Commission (FPC).

opinion as to whether or not it satisfies their criteria for the national interest.[2] If it does, then the question of safety of the site (D_2) is analyzed. Otherwise, revisions in the proposed site have to be made by the gas company or consortium.

Even if a site is considered to be in the national interest it does not mean that it will necessarily satisfy the safety guidelines of other federal agencies as well as local interests. Other relevant stakeholders or parties now enter the scene, each of whom has a set of attributes for consideration. *The Office of Pipeline Safety* (OPSO) is concerned that the facilities comply with the safety code of the National Fire Protection Association as well as the uniform building code with respect to maximum earthquake specifications. Another interested party is the *Coast Guard* who has jurisdiction over the entire portion of the LNG system that connects the tanker to the distribution system. Recently the Coast Guard has issued a set of regulations which apply to terminal siting, so that this agency is now an interested party.

At the local level, groups such as the *City Council* play a key role in determining whether or not a particular site satisfies their safety standards. In California there are two other agencies: the California Coastal Commission (CCC) and the California Public Utilities Commission (CPUC), both of whom have legislative responsibilities for determining whether a particular site is acceptable on the basis of local standards. In addition, there are frequently *public interest groups* who are concerned with the environmental safety impact of specific proposed sites.

[2] An example of one of these reports, with its full documentation, is DOE/ERA (1977).

Prior to 1977 there first had to be approval at the city or community level (e.g., by the Los Angeles City Council), and then at the state level through the CPUC. Both groups had to hold hearings to determine whether all interests were being served. Since 1977 the process at the state level has been centralized through the passage of the LNG Terminal Siting Act of 1977 whereby the California Public Utilities Commission was given sole authority to issue a siting permit.

The concept of acceptable risk has played a key role in the analysis of the relative safety of particular projects, but as we shall see below it has also created obstacles for final approval. The following procedure is employed: a detailed risk analysis of a proposed site specifies the chances of death per year (p) from LNG-related accidents to an individual at risk. If p is below some threshold level, p*, then the project is considered safe; if p > p* then it is not. The value of p* currently used by the FERC is 10^{-7} (i.e., 1 in 10 million) (OTA 1977).[3]

Role of Exogenous Events

What is most interesting about the historical record regarding these siting decisions, is the tremendous uncertainties associated with the final choice. Each interested party focuses on limited information and uses the data in different ways. Due to the difficulty of resolving stakeholder conflicts, a particular event can cause a reversal or reinvestigation of a particular decision if the case has not been finalized. Consider the four

[3]Keeney, *et al.* (1979) utilize this figure in support of the acceptability of a proposed LaSalle terminal. They claim in this case that it is less than 2% of 10^{-7}, so that the societal risk due to operation of the terminal is much less the OTA's criterion for social acceptance which appears to have originally been proposed by Starr (1969).

following examples:

1. In 1973 an LNG tank in Staten Island, New York, exploded and the roof collapsed burying 40 workers. There was no LNG in the tank but it had seeped through the insulation and caused a huge fire. A result of this explosion was the increased concern with the dangers of LNG by Staten Island residents. The neighborhood organization called BLAST, which was formed a year before the accident, attracted considerable attention and interest because of the media coverage of the tank explosion. In the context of the presented model (see Figure 1) a new interested party played a key role because of a random event. What may have been a foregone decision regarding the location of an LNG tank in Staten Island became problematical (Davis 1979).

2. The worst LNG accident occurred in 1944 when the storage tank operated by the East Ohio Gas Company in Cleveland ruptured, spilling LNG on adjacent streets and sewers. The liquid evaporated, the gas ignited and exploded, resulting in 128 deaths, 300 injuries and approximately $7 million in property damage. An investigation of this accident indicated that the tank failed because it was constructed of 3.5% nickel steel, which becomes brittle when it comes in contact with the extreme cold of LNG. All plants are now built with 9% nickel steel, aluminum or concrete and the storage tanks are surrounded by dikes capable of containing the contents of the tank if a rupture occurs. This example illustrates the impact of a particular incident on new regulations, which otherwise may not have been passed.

3. In December of 1976, the Los Angeles City Council voted to allow work to begin on an LNG terminal in San Pedro Bay. The following day an explosion ripped the oil tanker Sansinena in Los Angeles harbor leaving 9 dead and 50 injured. A week later the City Council commissioned a study as to the relative safety of the proposed site. They later approved the terminal. This explosion, although it had nothing to do with liquefied natural gas, alerted many Californians to the potential dangers of LNG.

4. Until the publication of the worst case scenario in 1976 on the possible consequences of a $300 million terminal in Oxnard in California, there was almost unanimous agreement by all stakeholders that Oxnard would be an ideal site for an LNG terminal. At the time even the Sierra Club was in favor of this location. (They changed their feelings about Oxnard in 1977.) A worst case scenario indicated that a spill of 125,000 cubic meters of LNG from all five tanks on a tanker would cause a vapor cloud which would affect 50,000 people. Residents could look on a map to determine whether the cloud covered one's own house (Ahern 1980a). No estimate of a probability was attached to this scenario. The graphic depiction of these consequences generated a public reaction by a small group organized by concerned citizens of Ventura County. The California legislature was influenced by this public reaction. One legislative staff member stressed that it was not possible to allow a site that would lead to a large number of deaths in a catastrophe.[4] Hence, new siting regulations were passed stating that no more

[4] This comment was made to John Lathrop in an interview in Sacramento, California, in July 1980, regarding the siting process of an LNG terminal.

than an average of 10 people per square mile could be within one mile of the terminal and no more than 60 within four miles of the terminal. The President's National Energy Plan incorporated similar population guidelines which effectively ruled out any high density areas as candidates for an LNG terminal.

In the case of California, Point Conception replaced Oxnard as the leading candidate for locating an LNG terminal. The introduction of Point Conception into the picture changed the responsibility for approving the site at the federal level. The ERA handles all cases where there is no interstate commerce while the FERC handles cases where there may be shipments of gas from other states. Oxnard involved shipments of gas from Indonesia only, so it came under the jurisdiction of the ERA. In the case of Point Conception, gas would be shipped from Alaska as well as from Indonesia, so the FERC now maintains primary responsibility (DOE/ERA 1977, p.38). The FERC conditionally approved Point Conception subject to state and local acceptance.

This example illustrates how the context in which information is presented (i.e., a worst case scenario) may provoke strong reactions by interested parties and eventually lead to legislative changes.

The picture painted in the four scenarios above highlights the critical role that institutional arrangements (e.g., the relationship between different interested parties) and legal considerations (e.g., specific regulations) play with respect to public policy decisions. What is also significant, is the importance of specific events in triggering new coalitions and frequently new legislation.

Where there are conflicts of interest between different parties, the balance of power normally lies with the stakeholder who is in the position to make the final decision. In the case of California, the key question was whether the California Energy Commission (CEC) or the California Public Utilities Commission (CPUC) would have final siting authority regarding the safety issue (i.e., D_2). Once CPUC was chosen over the more conservation-minded CEC as the agency with sole state permit authority, then the final decision regarding a site was probably different than it would have been had CEC played this role. Here again, the dynamics of the process had a critical bearing on the final decision.

IV. SUGGESTIONS FOR IMPROVING THE DECISION PROCESS: PRESCRIPTIVE ANALYSIS

This section, explores the role of prescriptive analysis given the descriptive model of choice specified above and the empirical data on LNG siting decision in the United States. I will focus on three techniques: decision analysis, assumptional analysis, interactive computer models, and policy analysis.

Role of Decision Analysis

An appropriate starting point is to determine how decision analysis may aid in this process. Keeney (1980) has shown how this approach can apply to structuring the siting decision but has focused primarily on a single decisionmaker rather than more than one interested party with conflicting objectives and different information bases. Many of the general concepts proposed by Keeney are relevant for the problem treated here. It is particularly important to specify the set of decisions $\{D_1, \ldots, D_n\}$ that have to be made, how they relate to each other, the role each stakeholder is likely to play with respect to each of the n decision points, and the relevant attributes that each of them are likely to utilize. It would be useful for each stakeholder to rank the relative importance of certain attributes as part of their final decision process.[5]

This is a time consuming process, but an important first step toward understanding what the critical differences are likely to be between interested parties in their evaluation of specific decisions. At the end of this process there is likely to be a recognition that to go any further with formal analysis, such as estimating utilities and probabilities of events occurring, would be tedious and not likely to yield benefits concommitant with the costs of undertaking this task. Furthermore, the different interested parties may feel that such a process would not be descriptive of their own behavior.

[5]See Keeney and Raiffa (1976) for a more detailed discussion as to techniques for ranking these attributes.

An alternative approach does present itself. Rather than trying to analyze each of the n subdecisions independently, it may be possible to focus on the final objective and examine the factors which influence the choice process. For example, in Section III the final objective was determining "an appropriate site, if any, in California for locating an LNG terminal." It should then be possible to construct a strategy/stakeholder matrix, such as the one represented in Figure 2 which in this case lists three possible sites and four types of stakeholders.

Stakeholder / Strategy	Department of Energy	State Agencies	Citizen Group	Local Agencies
Locate Site at Oxnard				
Locate Site at Point Conception				
Locate Site at Port of Los Angeles				

Figure 2. Stakeholder-Strategy Matrix for LNG Siting Decisions.

Coupled with this matrix one can also construct for each interested party a strategy/attribute matrix, which lists all possible considerations in judging the relative attractiveness of different sites. An example of this matrix is presented in Figure 3. The challenge, of course, is to fill in the cells of these two matrices which represent the perception of different sites by respective stakeholders (Figure 2) and how each site scores on each of the different attributes (Figure 3). The final matrix to complete the circle, is a stakeholder/attribute matrix such as the one shown in Figure 4.

Attribute / Strategy	Economic Factors	Environmental Factors	Safety Factors	Energy Policy
Locate Site at Oxnard				
Locate Site at Point Conception				
Locate Site at Port of Los Angeles				

Figure 3. Attribute-Strategy Matrix for LNG Siting Decisions.

Attribute / Stakeholder	Economic Factors	Environmental Factors	Safety Factors	Energy Policy
Department of Energy (DOE)				
State Agencies				
Citizen Group				
Local Agencies				

Figure 4. Stakeholder-Attribute Matrix for LNG Siting Decisions.

At this point it is difficult to know how to proceed using formal techniques such as decision analysis. Different stakeholders are likely to rank sites differently (Figure 2), will assign different costs and benefits to the attributes at each site (Figure 3) and will weigh the relative importance of each attribute differently (Figure 4). On the other hand, these matrices force the parties to recognize the tradeoffs in making a decision and hence reduce the relative importance of random events. These discrepancies may produce stakeholder conflicts which should be treated explicitly.

Use of Assumptional Analysis

One way to help understand and possibly reconcile differences between parties is to perform some type of assumptional analysis, such as the one developed by Mitroff, Emshoff, and Kilmann (1979). The authors have proposed a dialectical approach to strategic planning by forcing individuals to state the most important assumptions guiding their analysis and then to defend their position. Majone (1979) has suggested that the knowledge base on which to make decisions for these types of problems is so inadequate that such a process will enable one to explore avenues of disagreement and improve their understanding of the problem. In the above example, an attempt would be made to define the important attributes influencing each stakeholder's attitudes toward different sites, the weight given to each attribute and the impact that each of the different sites will have on each attribute.

If there are conflicts among stakeholders through this type of analysis, it may be necessary to evaluate the impact of choosing one site in period t should certain events occur in period t+1 and future periods. Mitroff, et al., discuss this process by asking what the impact will be if one chooses site 1, 2 or 3 based on certain assumptions which turn out to be false. They classify three types of errors of a policy assumption: (1) the real cost; (2) the visible cost; and (3) the reversibility cost. In terms of our example, there will be certain costs associated with any LNG siting decision should an event occur in future periods (e.g., an explosion) which changes the estimates of the costs and benefits of different states. By having conflicting opinions represented and examining the implications of a range of alternatives under different assumptions the rationality and legitimacy of decisions should be improved.

Role of Interactive Computer Models

If it is impossible to bring the different interested parties together, then other techniques may have to be used which involve indirect confrontation. One of the most promising approaches in theory, but one that has not been successfully applied in policy situations, is the development of interactive computer models for scenario generation. This type of decision support system would enable each interested party to construct his/her own scenario as to potential consequences of adopting one strategy over another. Having already constructed different matrices such as the ones shown in Figures 2 through 4, each stakeholder would be in a position to articulate the potential consequences of say, locating an LNG terminal at Oxnard, Port of Los Angeles, or Point Conception. At this point it would be possible to develop not only "worst case scenarios," but also less extreme situations, including the possibility that no accident occurs.[6]

There undoubtedly will be differences between the way interested parties view the situation, but the advantage of the interactive computer models is that these differences can then be openly discussed. In

[6] This approach differs from decision analysis by focusing on individual scenarios rather than a probability distribution over outcomes. For a more detailed discussion of decision support systems see Keen and Scott Morton (1978).

developing these scenarios, one can separate out the uncertainties, such as the probability of a particular situation occurring, from the more concrete data such as the losses which would take place conditional upon a particular event. One can then analyze separately very uncertain data (such as probability information) without linking them closely to a stream of events. Fairley's (1977) excellent discussion on difficulties associated with estimating low probabilities and their resulting consequences could then serve as a basis for a detailed exploration of this issue through sensitivity analyses. For example, suppose one estimated the annual probability of a severe accident to be between P_1 and P_2 with losses ranging from L_1 to L_2. One could then develop scenarios which examine the relative merits of different alternatives as one changed these estimates. If specific sites were preferred over a wide range of values for probabilities and losses then this would simplify the choice process. If the rankings changed as P_i and L_j were varied, then this would suggest that these estimates be refined.

The resolution of conflicts between interested parties may be extremely difficult even if one uses an assumptional analysis approach or constructs scenarios using an interactive modeling system. In fact, the descriptive model described in Section II suggests that interested parties may not want to get together to solve a particular problem unless they are forced to by existing legislation. Reconciliation of stakeholder conflicts is a time consuming and threatening process since it involves detailed analysis on the part of each of the groups and acceptance of responsibility for one's actions. From a political standpoint, this may not always be the wisest thing to do. Hence, the above prescriptive suggestions can only be viewed as a starting point for developing a dialogue. The final solution is likely to hinge on explicit legislation as to who "should" bear the costs of adopting certain measures. In the next subsection we briefly consider a set of policy options which may help reconcile these conflicts.

Use of Policy Analysis

There are three general classes of policy options which should be considered: (1) use of market mechanisms; (2) development of incentive systems; and (3) regulatory mechanisms.[7] In determining which one or combination of these three measures could be utilized, it is necessary to determine who is responsible for damages should an accident occur.

I will illustrate how these options can be utilized in facilitating the LNG siting decision; similar analysis can be undertaken for other policy decisions which affect a number of interested parties. In the case of LNG there are many different facilities which can cause an accident (e.g., ships, tanks, etc.) so it may be difficult to attribute fault to any one party. Furthermore, the ships, the LNG itself, and the terminals are owned by different subsidiaries or companies. The local, national and international jurisdictions make legal problems even more difficult (Davis 1979).

If LNG accidents are viewed primarily as a private responsibility by the gas consortium or supplier, then some form of insurance is the logical

[7]A more detailed discussion of the tradeoffs between the advantages and disadvantages of these methods appears in Stokey and Zeckhauser (1978).

market mechanism to utilize. A General Accounting Office (GAO) report of July 1978 concluded that injured parties could not be fully compensated for a serious accident under present liability arrangements. For this reason, market mechanisms with insurance firms providing adequate protection are not likely to cover all damages and there may be a reluctance on the part of gas companies or consortiums to invest in LNG projects unless the government provides some insurance against catastrophic losses.

With respect to *incentive systems*, it may be possible to provide special compensation to homeowners and individuals who reside in areas where LNG facilities are constructed. If land values drop then some type of lump sum payment might be desirable. Lower energy rates can also compensate residents for the increased risk of having an LNG terminal in their "back yard." Terminal owners who saw a need for a liability fund could finance it by a tax on LNG sales. These types of subsidies and taxes would shift some of the economic burden from those bearing the physical risk to residents and businesses who are benefiting from the facilities. If the government feels that the LNG terminals yield substantial public benefits, then they may want to cover catastrophic losses through special funds such as those earmarked by the Price Anderson Act for nuclear accidents. Note that each of the above incentive systems implies a set of value judgments as to whom should benefit and whom should bear the costs of constructing LNG facilities.

Finally, it may be deemed desirable to have special regulations to protect the public from certain risks. Legislation, with respect to location of LNG terminals, have recently reflected this concern by requiring certain conditions on population density around an LNG terminal as well as specifying certain construction standards on tanks and dikes around the terminal. As pointed out above, many of these regulations were passed because of some specific accident or crisis that pointed out the need for these provisions.

By adopting any of these policy recommendations one is implicitly (if not explicitly) answering questions as to the weight that should be assigned to each of the relevant stakeholders in any evaluation process. Furthermore, the adoption of any policy provides guidelines as to how society views the tradeoff between efficiency and distributional considerations.

V. CONCLUSIONS

At the heart of the problem for societal decisionmaking on low probability events is the increasing recognition that there is great uncertainty on the data necessary to undertake any analysis: the probability of a loss occurring, consequences of disasters of different magnitudes, and how well certain protective measures will mitigate these losses. It is thus not surprising that there are large differences in stakeholder estimates on these figures.

As I have tried to emphasize in this paper, this situation causes a set of dynamics that are only partially predictable because of the occurrence of random events. On the other hand, there are ways of directly addressing the problem by having policy makers indicate what aspects should be viewed as private and public responsibilities, who should benefit and lose by any set of decisions, and what actions in the form of market mechanisms, incentives, or regulations should be taken to produce a particular effect. The results may differ from what one expects, however, because one is dealing with a situation fraught with uncertainty on most dimensions. The challenge in dealing with societal decisionmaking for low probability events is to be resilient in the face of uncertainty. Any other strategy is likely to prove catastrophic.

REFERENCES

Ahern, William. 1980a. "California Meets the LNG Terminal," *Coastal Zone Management Journal*, 7:185-221.

Ahern, W. 1980b. "The Role of Technical Analyses in California Energy Facility Siting Decisions," Paper prepared for the LEG Case Study Task Force Meeting, IIASA, Laxenburg, Austria, September 23-26, 1980.

Bettmann, J. 1979. *An Information Processing Theory of Consumer Choice*. Reading, Massachusetts: Addison Wesley.

Cyert, R., and J. March. 1963. *A Behavioral Theory of the Firm*. Englewood Cliffs, New Jersey: Prentice Hall.

Davis, L.N. 1979. *Frozen Fire*. (Friends of the Earth).

DOE/ERA. 1977. *Opinion and Order on Importation of Liquefied Natural Gas from Indonesia, Opinion Number One*, Washington, DC: Department of Energy.

Deutsch, R.W. 1980. "Siting an LNG Facility in California: The Regulatory Framework and the Factors Involved in the Decision Making Process." Paper prepared for the L.E.G. Case Study Task Force Meeting, IIASA, Laxenburg, Austria, September 23-26, 1980.

Fairley, W. 1977. "Evaluating the 'Small' Probability of a Catastrophic Accident from the Marine Transport of Liquefied Natural Gas," in Fairley and Mosteller (eds.), *Statistics and Public Policy*, Reading, Massachusetts: Addison Wesley.

Fischhoff, B., P. Slovic, and S. Lichtenstein. (in press). "Lay Foibles and Expert Fables in Judgments about Risk," in T. O'Riordan and R.K. Turner (eds.), *Progress in Resource Management and Environment*

Planning, Vol. 3, Chichester: Wiley.

Hersey, J., H. Kunreuther, and P. Schoemaker. 1980. "Two-Piece von Neumann-Morgenstern Utility Functions: Some Methodological and Empirical Observations," Department of Decision Sciences Working Paper, Wharton School, University of Pennsylvania, July.

Jackson, J., and H. Kunreuther. 1980. "Low Probability Events and Determining Acceptable Risk: The Case of Nuclear Regulation," (mimeo).

Keen, P., Scott Morton. 1978. *Decision Support Systems: An Organizational Perspective*. Reading, Massachusetts: Addison Wesley.

Keeney, R. 1980. *Siting Energy Facilities*. New York: Academic Press.

Keeney, R., and H. Raiffa. 1976. *Decisions with Multiple Objectives*. New York: John Wiley.

Keeney, R., R. Kulkarn, and K. Nair. 1979. "A Risk Analysis of an LNG Terminal." *Omega*, 7:191-205.

Kunreuther, H., R. Ginsberg, L. Miller, P. Sagi, P. Slovic, B. Borka, and N. Katz. 1978. *Disaster Insurance Protection: Public Policy Lessons*. New York: John Wiley.

Lathrop, John. 1980. "The Role of Risk Assessment in Facility Siting: An Example from California," WP-80-150, Laxenburg, Austria: International Institute for Applied Systems Analysis (IIASA), October.

Lawless, J. 1977. *Technology and Social Shock*. New Brunswick, New Jersey: Rutgers University Press.

Lindblom, C. 1959. "The Science of Muddling Through." *Public Administration Review* 19:79-88.

Lindblom, C. 1965. *The Intelligence of Democracy*. New York: MacMillan.

Linnerooth, J. 1980. "A Short History of the California LNG Terminal." WP-80-155, Laxenburg, Austria: IIASA, November.

Majone, N. 1979. "Process and Outcome in Regulatory Decisions," *American Behavioral Scientist* 22:561-583.

March, J. 1978. "Bounded Rationality, Ambiguity, and the Engineering of Choice," *Bell Journal of Economics*, 9:587-608, Spring.

March, J., and J. Olsen. 1976. *Ambiguity and Choice in Organizations*. Bergen, Norway: Universtetsforlaget.

Mitroff, I., J. Emshoff, and R. Kilmann. 1979. "Assumptional Analysis: A Methodology for Strategic Problem Solving," *Management Science*, 6:583-593.

Office of Technology Assessment (OTA). 1977. *Transportation of Liquefied Natural Gas*, Washington, DC: Office of Technology Assessment.

Simon, H. 1978. "On How to Decide What to Do," *Bell Journal of Economics*, 9:494-507, Spring.

Starr, C. 1969. "Social Benefit versus Technological Risk," *Science*, 165:1232-38.

Stokey, E., and R. Zeckhauser. 1978. *Primer for Policy Analysis*. New York: Norton.

Tversky, A., and D. Kahneman. 1974. "Judgment Under Uncertainty: Heuristics and Biases," *Science*, 185:1124-31.

Tversky, A., and D. Kahneman. (in press) "The Framing of Decisions and the Psychology of Choice," *Science*.

Walker, J. 1977. "Setting the Agenda in the US Senate: A Theory of Problem Selection," *British Journal of Political Science*, 7:423-445.

DISCUSSION COMMENTS

J. SCHWARZ: I think that we on the one hand--the stakeholders, as you call them--have already done a lot of research in the technical way at least, to give some weight to their own alternatives. Later on different parties then come into the process without the benefit of a large amount of research; they can do only some literature review. Hence, they have weaker *arguments* in the eyes of expert advisers of decision-makers.

REIJNDERS: I had a more general remark related to the discussion that has taken place so far this morning. I feel rather important additions should be made in the general area of "rights." Here I think especially of the "right to life" concept, and the right to be saved from undue interference by others as proposed by John Stewart Mill. These kinds of rights can bring grave constraints to anything you do in this area. I see the "rights" tradition as a moral tradition that is very important to the general population. Thus rights do play a major role and should be worked into the framework.

KUNREUTHER: It seems to me that there is a set of moral considerations that has not been included in our analysis. The analyst is then faced with some *very* very difficult tradeoffs in terms of what he or she should do. For example, take the concept of sacredness of life. Everyone may agree that life is sacred, but at the same time everyone will agree that there are limited resources that one can invest in different projects. The minute one imposes limited resources then there have to be tradeoffs as to where one invests that money. For example, in the health area we know there are tradeoffs between investing in special devices that save one individual's life, such as a kidney machine, rather than putting a good deal of money into research that might save a large number of unidentified lives. It strikes me that this particular point will come up during later discussions as to how different groups are going to look at the problem. Any individual living in an area is going to respond by saying that is my *life*, and they have no right to take my life when they invest in this terminal in this particular location.

MEHTA: I would like to make a general comment, recognizing that the decisions on energy and siting policies are essentially political ones. Politicians do not always act rationally nor do companies. You can be sure that one company will take a different action towards the commercial risk involved, than another company. Hence, the position on siting will not depend on any detailed analyses of the general type that we have been talking about. What we might more usefully do is to focus our attention on the more technical problems, which we can at least throw some light upon.

These are the problems that were mentioned earlier, what we mean by "risk" and "safety." What are the differences between the various types of risks? What is the focusing effect of risk on the local community? Was a risk accepted generally by the population at large? Also the question, although a difficult one, of what is an acceptable level of risk? There are no finite answers. There is no dividing line where you say that something is acceptable or not depending on which side of the line it falls. What we could have perhaps is a guideline which can be used as a tool by the politicians in arriving at the decisions that they will have to make at the end of the day. Because if we do not do that then we are in great danger of the politicians making the decisions on assumptions entirely different from those upon which the scientists are basing their judgment about what risk is involved, and what is acceptable? And those assumptions and judgments may again be quite different from the perceptions of the community at risk.

INFORMATION PAPER:
LNG SITING IN THE NETHERLANDS

Michiel Schwarz
IIASA

1. INTRODUCTION

The following narrative sets out the major developments in the Netherlands concerning the decision-making process as regards a terminal for LNG. It is a sketchy overview of the major events, largely taking place between 1975 and 1978, and leading up to the decision by the Dutch cabinet to locate an LNG terminal (for tankers of 125,000m^3) at a site in the Eemshaven.

The main part of this paper deals with the discussions on the location of an LNG terminal in the Netherlands, following a contractual agreement between the Dutch Gas Company, NV Nederlandse Gasunie, and the Algerian company Sonatrach, for the supply of LNG to the Netherlands, starting in 1985. The political debate in the Netherlands finally focused upon two alternative sites: Maasvlakte (near Rotterdam) in the province of Zuid-Holland, and Eemshaven (near the Northern port of Delfzijl) in the province of Groningen. After considerable debate at various levels and extensive consultations between the government and different interested parties, the Dutch cabinet finally decided in August 1978 in favor of the Eemshaven site.

Emphasis has been placed here upon the major inputs to the national government and the cabinet, such as advisory reports, local authorities' views, and discussions at various levels, which seem to have been most influential in determining the outcome of the governmental policy process. Most of this paper is limited to basic information on the way events developed in the Netherlands; some preliminary analytical observations, however, have been made at the end of the paper (Section 12).

2. MAJOR INTERESTED PARTIES AND KEY EVENTS--A SUMMARY

Many different "interested parties" were involved at various stages of the decision process on LNG in the Netherlands. The major parties are summarized below:

... National Government and Cabinet--most of the sixteen ministries and Cabinet Ministers were involved in making the final decision on the location of an LNG terminal;

... Local Government: Zuid-Holland--in the province of Zuid-Holland, the provincial legislature and the municipality of Rotterdam had to give approval for an LNG terminal in their region, while the Rijnmond body fulfilled an advisory function to the provincial government;

... Local Government: Groningen--the provincial government of Groningen had to approve any siting in its region, together with the municipality responsible for the Eemshaven harbor region;

... ICONA--the major advisory body on LNG siting to the Cabinet, in which almost all of the Dutch ministry departments were represented;

... NV Nederlandse Gasunie--the partially state-owned company responsible for buying, selling and distributing natural gas in the Netherlands;

... Sonatrach--the Algerian gas company which as of 1985 would become the Netherlands' major foreign supplier of LNG (4,000 million m^3/year);

... Parliament--the Dutch house of Representatives, which by law had to approve the Cabinet's decision, before it could become effective.

The <u>major events</u> in the decision-making process on LNG in the Netherlands took place in 1977 and 1978, as the following summary depicts:

June 1977	NV Nederlandse Gasunie signs contract with Algerian company Sonatrach for sale of 4,000 m^3 LNG for the 1985-2005 period;
October 1977	ICONA set up; its first task is to study LNG import and terminal;
October 1977	Ministry of Economic Affairs approves Algerian LNG contract; location of LNG terminal to be named by 31 October 1978;
October 1977	ICONA recommends LNG imports at one of two possible sites, Maasvlakte or artifical North Sea Island;
December 1977	Delfzijl Harbor is approached by NV Nederlandse Gasunie, to discuss Eemshaven as possible LNG site (which was earlier rejected by ICONA as viable option);
February 1978	Cabinet considers sites at Maasvlakte and Eemshaven;
March 1978	Local authorities in Zuid-Holland and Groningen start public hearings and local decision procedures; to be completed by 1 July;

June 1978	ICONA submits final report to the cabinet: favors Maasvlakte site;
July/ August 1978	Continued discussions on siting alternatives between cabinet, ministries, local authorities, and other parties;
August 1978	Cabinet announces its decision: LNG terminal should go to Eemshaven;
October 1978	Parliamentry debate does not alter cabinet's decision; Sonatrach is informed of the selection of Eemshaven site.

3. NATIONAL GOVERNMENT--INITIAL INVOLVEMENT

Government interest and involvement regarding the import of LNG and siting of facilities intensified in 1975, when the Dutch gas company, NV Nederlandse Gasunie*, requested an official view from the cabinet, concerning the possibilities for off-shore or land-based terminals for the reception and storage of LNG in the Netherlands. This action resulted in the setting up (by the Ministry of Traffic and Waterworks) of the so called STUNET, "steering group for the study of North Sea islands and terminals"** STUNET's first major task was to advise the cabinet on the feasibility and desirability of a Dutch LNG terminal to be located offshore on an artificial island in the North Sea compared to the possibilities for onshore facilities.

STUNET completed its first report in March 1977*** at a time when the LNG issue had been little debated outside the gas industry or governmental groups in the Netherlands. Against a background of rising interest and speculation concerning LNG, the government, however, decided to publish the report, four months later. The major conclusion of STUNET was that, having taken into account aspects of safety, environmental impact, technological factors, costs vs. benefits, and risk reduction, the construction of a Dutch LNG terminal should be considered--either at an artifical island off the Dutch coast or at the Maasvlakte (the Rotterdam harbor area). Safety considerations were partially based upon a risk analysis of LNG by TNO (the Dutch organization for applied scientific research), commissioned by the Ministry for Social Affairs. The feasibility of other onshore alternatives as LNG sites, such as Delfzijl-Eemshaven (in the North-East of the Netherlands) and Vlissingen (South-West) were rejected by STUNET on either nautical and/or safety grounds. As regards offshore vs. onshore advantages, STUNET concluded that a Maasvlakte site would be cheaper than an Island terminal, whilst the safety aspect would favor an offshore terminal. Environmental and other aspects which were studied failed to establish a clear difference between sites.

---

*National Gas Company for buying, selling and distributing natural gas in the Netherlands. Owned jointly by the State (10%), DSM (Dutch State Mines) (40%), Shell NL (25%), Esso (25%).

**Stuurgroep Studie Noordzee-eilanden en Terminal.

***LNG Terminal in de Noordzee rapport van de projectgroep LNG Terminal STUNET, Maart 1977.

4. ICONA--INTERNAL DEBATE IN GOVERNMENT

The STUNET report was submitted to an interdepartmental government committee, called ICONA, (Interdepartementale Coordinatielcommissie voor Noordzee-aangelegenheden), which was established by the government in 1977 to coordinate among the different ministeries, the decision-making process (including policy advice and implementation) on affairs concerning the North Sea. Discussions between NV Nederlandse Gasunie and the Algerian state company Sonatrach for the sale of Algerian LNG to the Netherlands were by then underway and ICONA was given the task of studying the various issues (including financial, technical, economic, safety, social and environmental aspects) involved in the upcoming decisions concerning reception and storage of LNG and to prepare a cabinet decision. It is within the ICONA committee that the major policy discussions on the import of and siting of facilities for LNG took place in 1977 and 1978, leading up to a single cabinet position. Representatives of fifteen Dutch government departments (of the 16 ministeries which make up the Cabinet) were represented in ICONA, which acts as an advisory body to the Dutch Cabinet.

ICONA's first policy recommendations ("Beleidsadvies bij het 'Rapport van de projectgroep LNG terminal', ICONA, oktober 1977), were largely based on advice from STUNET; they were favorable to LNG import and argued for a Dutch terminal, urging the need for further research into the location (focusing on an offshore terminal and the Maasvlakte site) and into the siting conditions of LNG facilities. According to ICONA, the risks involved in the handling of LNG were outweighed by the perceived advantages for Dutch energy policy (diversification of energy sources, one of the Dutch's stated aims) and for the environment ("gas as a clean energy source").

ICONA's policy recommendations, however, were not supported by all of its members, and representatives of the Ministry of Public Health and the Environment published a minority view. According to the latter the location of LNG facilities at the Maasvlakte were <u>not</u> acceptable because of the risk of explosions and other accidents in the heavily populated area around Rotterdam. Furthermore, the "dissenting" representative argued that the committee had not taken into account the "worst possible accident scenario". Moreover, he questioned the necessity for the importation of LNG into the Netherlands from the point of view of energy supply. Also the Ministry for Science Policy stated its grave reservations as regards the policy recommendations of ICONA.

5. INDUSTRY MOVES AHEAD

By the time the first policy recommendations of ICONA were submitted to the Cabinet, in October 1977, the NV Nederlandse Gasunie had signed a contract (in June 1977) with the Algerian company Sonatrach for the importation of 4000 million m^3 a year of LNG over a period of twenty years, (1985-2005). The contract was conditional, requiring official approval of the Ministry of Economic Affairs, by 31 October 1977. The Cabinet (who would be responsible for any major decision on LNG imports) was hereby called into "active involvement" in the LNG decision-making process. Within the mandate of Dutch "energy policy" but apparently with other cabinet ministers or parliament, the Minister of Economic Affairs subsequently approved the Gasunie-Sonatrach contract on 18 October 1977. A side-letter attached to the contract specified that by 31 October 1978, NV Gasunie was obliged to notify Sonatrach about the location of the LNG importation site. (If this proved to be impossible, the contract would have become void.) The LNG siting debate was hereby officially opened, strictly leaving open the question where the LNG would be shipped to (onshore or offshore, inside or outside the Netherlands), or indeed whether a Dutch LNG site would be established at all.

The machinery for national and local government decision-making procedures was then set into motion. ICONA continued its advisory role, more advisors were called in by the government (such as the State Planning Committee, Rijksplanologische Commissie), and the Inter-Ministerial Committee for Environmental Health, Interdepartmentale Coordinatiecommissie voor de Milieuhygiene (ICMH), and local authorities were asked for their views.

6. LOCAL AUTHORITIES GET INVOLVED

Working on the assumption that the only viable onshore LNG terminal site was the Maasvlakte area, three main local bodies became officially involved in the decision processes: (1) The Municipality of Rotterdam, (2) The Public Body of the Rijnmond Region, and (3) The Province of Zuid-Holland. Through various laws and environmental and health legislation these three local authorities had an important role to play in approving or disapproving a possible LNG site at the Maasvlakte.

By the end of 1977 some of the interested parties in local LNG debate about a Maasvlakte terminal had begun to air their respective views. Rotterdam, in particular the harbor authorities, were in favor of an LNG terminal, largely because of the economic benefits it would bring to the largest harbor of Europe. The safety aspects received relatively little attention in a Rotterdam harbor report of December 1977 ("LNG Aanvoer via Rotterdam", Haven van Rotterdam, oktober 1977). Rijnmond, however, was more critical of plans for an LNG terminal near Rotterdam, stressing the environmental and safety problems in the already heavily congested area around Rotterdam.

As local authorities concerned with the Rotterdam area continued discussions about a common policy view, an alternative site was being introduced into the debate. NV Gasunie had invited the Harbor of Delfzijl (in the Province of Groningen, North-Eastern part of the Netherlands) for discussions about the possibility of an LNG terminal in the Eemshaven region. Delfzijl Harbor, which is the entrance to the Eemshaven region, and the local government of the province of Groningen were highly interested in the latest plans of the Gasunie; they rapidly formed a common front against Rotterdam, and set out new marine, cost-benefit and safety studies* regarding an Eemshaven terminal. Initial

---

*TNO completed another risk assessment in February 1978, focusing on the Eemshaven as an LNG site.

results were positive. In February 1978 the province of Groningen, and the harbor of Delfzijl made an official request to the government to include Eemshaven as a contender for the Dutch LNG terminal. The national government, meanwhile, awaited a second advisory report from ICONA, in preparation of an early draft policy statement by the Cabinet.

7. MORE ADVICE FROM ICONA AND A PRELIMINARY GOVERNMENT POLICY

The second advisory report from ICONA to the Dutch Cabinet focused on three main questions: (1) the need for the import of LNG; (2) the need for a domestic LNG terminal, rather than the use of an LNG terminal abroad (with further transport via pipeline to the Netherlands); and (3) the location of a Dutch domestic LNG site (if required). ICONA submitted its advice to the Dutch Cabinet on 23 February 1978 ("Nader advies van de ICONA insake de aanvoer van vloeibaar aardgas (LNG) in Nederland", ICONA, 21 februari 1978). It concluded that importation of LNG was desirable and that it should take place at a Dutch LNG terminal (on the grounds of energy policy, employment benefits and the requisition of technical know-how). As regards the exact location, ICONA had not (at that point) considered the Eemshaven site as a viable option and concluded that two of the considered sites at the Maasvlakte area (called "A" and "B") should be given preference. Major considerations involved included aspects of safety, environmental hygiene, planning, economic activity, cost and timing required for realization. No final single advice on the location of the terminal, however, was provided by ICONA, on the grounds that questions of perceived risks of an LNG terminal should be further analysed in later stages of the decision process. As a result of the re-introduction of the Eemshaven alternative, furthermore, ICONA stressed that additional studies on this site in Groningen should be carried out since so far this had not been the case.

Again the advice from ICONA was not unanimous: the representative of the Ministry for Public Health and Environment repeated his arguments against accepting the Maasvlakte as a siting area and stated that alternatives to LNG had not been adequately explored and considered. Furthermore, the deputy representative of another Ministry, Public Housing and Planning, took a position "close" to the above point of view.

Having considered the advice of ICONA, as well as other advisory bodies, the government announced (in March 1978) its preliminary policy as regards the LNG import and siting question, (Voorlopig Regeringsstandpunt, Tweede Kamer der Staten-Generaal, Zitting 1977-78, 14 626, nr. 6, 13 maart 1978). Stressing once again the need for importing LNG into the Netherlands, the Cabinet's view consisted of three main points: (i) two Maasvlakte sites should be considered and the Delfzijl-Eemshaven site should not be ruled out; (ii) the preliminary government position should be communicated as soon as possible to local authorities involved, in order to allow the latter to comment on the plans by 1 July 1978; (iii) additional risk reducing measures should be taken in particular regarding the LNG tankers and shipping routes. The Cabinet thus took the unusual step of requesting approval from local authorities for an LNG site <u>before</u> normal planning permission procedures had been set into motion.

8. LOCAL AUTHORITIES DEBATE LNG

Following the request from the government, local authorities in the provinces of Zuid-Holland and Groningen started their procedures as part of the LNG decision process. Public hearings and information meetings were held, inviting all interested parties and individuals; the matter was widely debated in the respective councils of representatives, both at the provincial and municipal level. By the end of June 1978 the views of the various official parties involved in Groningen and Zuid-Holland became clear.

In the North, the Groningen authorities unanimously accepted plans for a LNG terminal in the Eemshaven and urged the Cabinet to take a decision in its favor, mainly on the grounds of perceived regional economic benefits. Local authorities concerned with the Maasvlakte site, however, were divided in their views. The Board of Governors of Rotterdam and of the Province of Zuid-Holland were in favor of a Maasvlakte site (B only, A unacceptable) for the LNG terminal only after certain environmental/safety and other conditions had been met. The public body Rijnmond, on the other hand, (which, incidentally, had only an advisory function), was of the opinion that the arrival site of the LNG tankers and storage site should be separated: storage in the Maasvlakte area was considered acceptable, but the import/arrival site should not be located there, but instead at an offshore terminal.

These various viewpoints emerged after considerable political debates at public hearings and at council meetings at various levels, including inputs of environmental (the major "umbrella" organization for environmental groups was the so-called werkgroep Noordzee) groups and other critical analysts of the LNG siting decision process. At the provincial level planning permission for a LNG terminal could have been rejected altogether.

9. THE GOVERNMENT NARROWS DOWN ON ALTERNATIVE SITES

Before the final views of the various local authorities had reached the government, the cabinet had announced a further policy view, following additional advice from ICONA and others. A third ICONA report, focusing on the Eemshaven option compared to the other possible terminal sites had reached the government in early June 1978. (Aanvullend advies van de ICONA inzake de mogelijkheid van aanlanding van vloeibaar aardgas in het Eemshaven gebied, 1 juni 1978, ICONA, nr. 147.) ICONA's major conclusion was: "also after study of the Eemshaven location, preference should be given to the Maasvlakte site for the establishment of a LNG terminal." ICONA had not taken into consideration aspects of political influence and of maximum accidents with LNG, when comparing the two sites--Eemshaven and Maasvlakte. ICONA also stressed that it had not taken into account the importance that should be given in a final decision to the risk <u>perceived</u> by the population.

The next government statement followed on 13 June 1978 and read "The Cabinet considers Eemshaven to be a possible site for an LNG terminal; be it that this location involves considerable difficulties". After further consultation between the national government and local authorities the government decided on 20 July that now the selection of sites, concentrated on two locations only, i.e. Maasvlakte B and Eemshaven. This view was in agreement with further advice from ICONA who, however, continued to stress that they gave preference to the Maasvlakte site.

In July and August 1978 the "battle" between Groningen and Rotterdam intensified. Various publications were submitted to the government by the different parties and visits were made by delegations from Rotterdam and Groningen to put forward their respective cases. Groningen had the advantage that it was able to put up a common front, including the Dutch trade union movement (which supported an Eemshaven site); also, the Royal Commission of the Province of Groningen moved in personally to argue his case. Local bodies in Zuid-Holland largely remained divided because of the safety issues.

10. GOVERNMENT SELECTS EEMSHAVEN SITE

Formal and informal contacts between the various parties, the "lobbying" process, in preparation for a Cabinet decision came to an end when the Cabinet met on 25 August 1978 and decided in favor of the Eemshaven site. The choice was made, the cabinet stated, in particular on grounds concerning regional economic policy and the expected boost for employment, etc. the LNG activities were expected to give to the "depressed" area of the north-east (which deserves special attention under Dutch regional policy). The Government policy paper identified ten major aspects which had been taken into consideration, namely: energy policy, technical/marine factors, safety/risk, environmental hygiene, environmental planning, economic activity, costs, agreement with local authorities involved, international arrangements, and time of completion of terminal. Major differences between the two prime sites are cost (Eemshaven will be over 100 million dollars more expensive), safety and risk (according to the government the chance of an accident is smaller at Eemshaven and the maximum effect of a disaster is estimated to be one order of magnitude smaller at Eemshaven), environmental considerations (environmental effects are greater at Eemshaven) and economic activity (regional policy favored the Eemshaven site). As regards the aspect of safety, the government paper states that despite the apparently safer location of Eemshaven, it must be concluded that quantification and comparison of risk is problematic and no clear preference of either site should be attached to the risk assessments.

The government noted that the possible construction of a LNG terminal at the Maasvlakte would have had to be accompanied by a set of conditions, mostly relating to safety, put forward by the local authorities in Zuid-Holland. (The province of Groningen, in contrast, gave the government what was in effect an unconditional approval for an Eemshaven site). It is interesting to note that the government also stated that the NV Gasunie had declared a clear preference for the Maasvlakte site.

11. PARLIAMENTARY DEBATE ON LNG

As is customary in Dutch politics, the government was obliged to defend its policies in Parliament. Following the meetings of a special parliamentary committee on LNG, which included talks with the responsible Cabinet Ministers, the LNG issue was debated in a plenary session of the lower chamber of Parliament on 26 and 31 October 1979. Major opposition to the government's proposed policies came from the (left-of-center) opposition parties. Major issues which were debated concerned: (i) safety and environmental health aspects of LNG terminals, (ii) the need for LNG import rather than natural gas, (iii) the possibility of extension of the date a site had to be named (according to the original contract), and (iv) the possibility of exchange of gas between Algeria, the Netherlands and Italy. (The Netherlands is contracted to supply Italy with Dutch natural gas via pipeline until 1994.) Several motions were tabled and debated on those issues. The outcome of the voting was largely in favor of the government's planned policy. It is important to note that a rejection of the major facets of the government's policy paper by parliament would almost certainly have resulted in a fall of the Cabinet and new general elections. It may thus be said that the choice of members of parliament was effectively between accepting the Cabinet's policies or voting out the Cabinet. Following the debate in Parliament, the government was able to officially put forward the Eemshaven site for the construction of an LNG terminal, and to have this decision communicated to Sonatrach of Algeria.

12. PRELIMINARY ANALYSIS OF THE DECISION PROCESS

As regards the decision-making process on LNG siting in the Netherlands, the following preliminary comments may be made:

... most of the discussion took place within the overall framework of Dutch energy policy, and the need for importation of natural gas was largely acknowledged by the different parties;

... the Eemshaven site which was finally selected, was introduced as a viable option through dealings outside national government (between Groningen Province and NV Gasunie), and at a fairly late stage of discussion;

... the discussion on the siting of an LNG terminal in the Netherlands took place after a contract for the importation of LNG had already been signed and approved by the government under certain conditions;

... in the early period of the decision process discussions on an LNG terminal were limited to ministerial departments and official governmental advisory bodies, without external bodies or interest groups being in a position to influence the process;

... public hearings and dissemination of public information on the LNG issue took place at a fairly late stage of the process and was restricted to the level of local authorities;

... local authorities were hardly introduced into the discussion until after the government had made some principle policy decision and required insights in the likelihood of acquiring local planning permission for its plans;

... risk analysis were carried out but played a relatively minor role in the policy debate, risk assessment studies were used by some and largely neglected by others;

... once some basic safety requirements were perceived to have been met, the policy debate shifted to other aspects of an LNG siting issue;

... the common front of the Province of Groningen versus the divided stand of Zuid-Holland, primarily because of concerns about safety, was an important factor in the outcome of the decision process in favor of the first;

... the final decision on the location of the LNG site was primarily based on political rather than technical (including safety) grounds;

... the Cabinet's decision was in contrast with the recommendation of ICONA as well as the advice from NV Nederlandse Gasunie.

PLANNING FOR HAZARD: AN APPRAISAL OF SAFETY CONSIDERATIONS FOR THE FIFE GAS PLANT

S.M. Macgill

ABSTRACT

In this paper the background to the decision to allow the construction of large scale liquefied energy gas facilities at Mossmorran and Braefoot Bay in Fife, Scotland is reviewed. Serious criticisms are identified, notably, an institutional procedure that cannot be seen to be fair, a completely inadequate definition of acceptability of risk for a project in which substantial issues of public safety are raised, and several specific points on which accepted statements on hazard may be questioned. The criticisms in this paper are not addressed directly at the decision itself, but rather at the way it appears to have been reached.

S.M. Macgill
August 1980

This paper represents only a preliminary review of aspects of the decision process. A more substantial case study undertaken more recently by the author is to be issued as an IIASA Working Paper.

S.M. Macgill
September 1981

1. INTRODUCTION

The joint developments of Shell and Esso to introduce large scale liquefied energy gas (l.e.g.) facilities at Mossmorran and Braefoot Bay in Fife, Scotland, involve substantial issues of public safety. It is the intention in this paper to review the way in which public safety issues were considered within the decision making process which led to the granting of planning permission for these developments. This involves taking account of (i) the adequacy of the institutional framework through which the decision was made, the cornerstone of this framework as regards public participation being a Public Inquiry convened during June and July 1977; (ii) the nature of the safety considerations that were advanced by various contributing parties within this framework, most important here being issues relating to the acceptability of the risk to be imposed on the public.

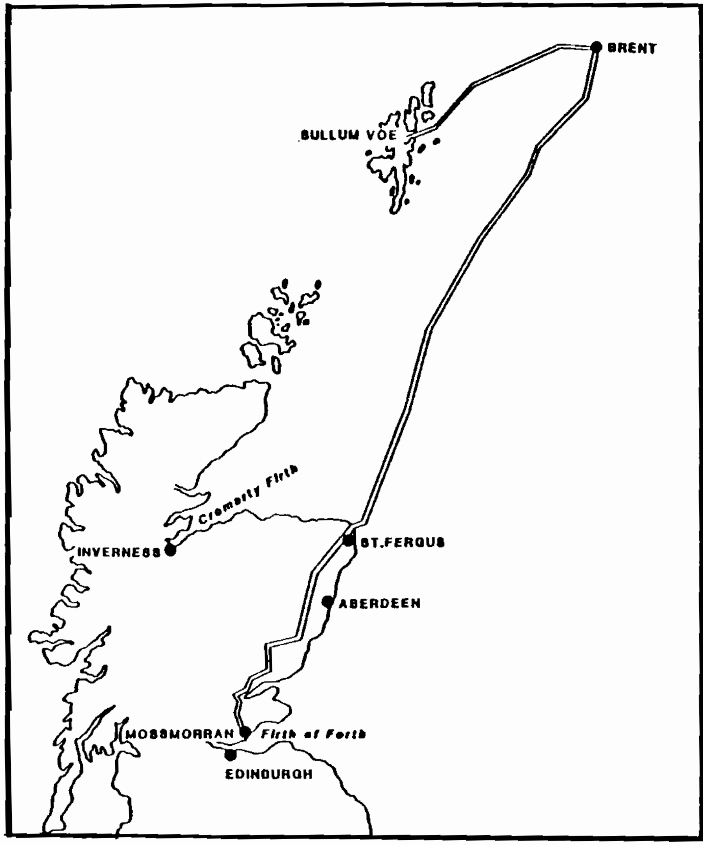
Many of the criticisms to emerge from the background to the Fife decision have by now widely rehearsed parallels in other fields, notably in connection with nuclear power, Windscale in particular (Breach 1978),and more recently concerning the Belvoir Inquiry (Cope and Hills 1979; Arguile 1980). Criticism may stem from mismatch in financial and technical resources between proposers and objectors; the ritual of a Public Inquiry where a Planning Inquiry Commission would have been a more suitable platform for debate given the technical complexity of some of the issues involved, the importance of the question of alternative sites and the fact that in many respects this is a national rather than a local project; the marked lack of confidence in the public sector institutions that were involved--local authorities, the Health and Safety Executive, and the Secretary of State--far from commanding public confidence and respect became targets for criticism and derision: the apparent inadequacy in official response to many of the objections that were raised; the overriding impression that objectors had not been given a fair hearing, and that the Public Inquiry was merely window dressing for a foregone conclusion.

Such criticisms can be seen either as the inevitable and desperate reaction of objectors to an unfavourable final decision, or as genuine and understandable grievances about an unfair system of public debate that is in urgent need of revision (Sieghart 1979; Pearce, Edwards and Beuret 1979).

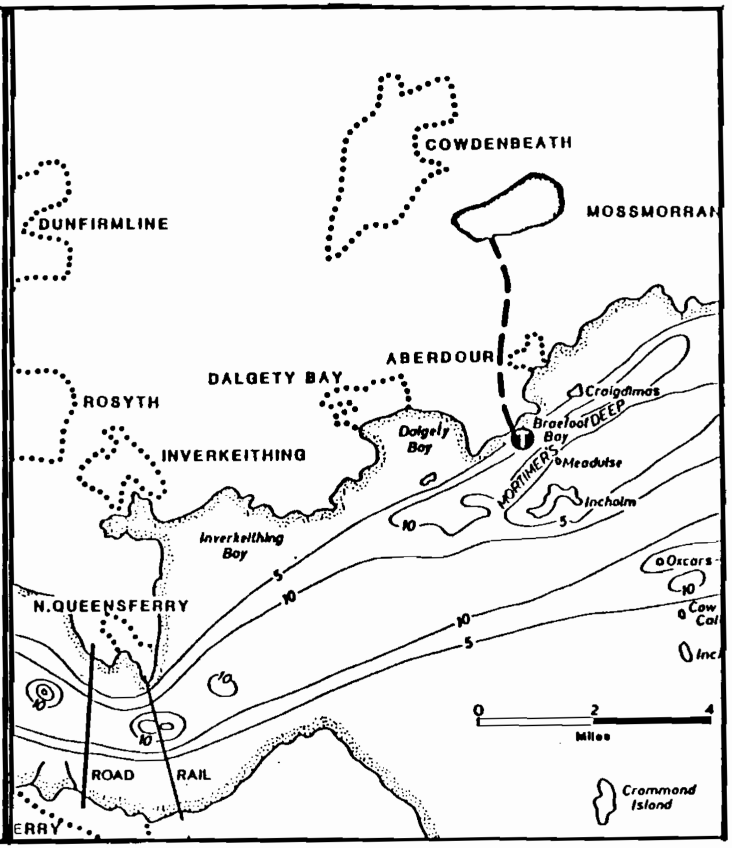
2. THE FIFE GAS PLANT: BRIEF DESCRIPTION

The Fife developments involve the construction of a natural gas liquids separation plant and an ethylene cracker at Mossmorran with associated marine terminal at Braefoot Bay, and relevant pipeline, storage and loading facilities. The locations of these facilities and their capacities and interrelationships are illustrated in Figures 1 and 2. These are large scale facilities by most standards (the Braefoot Bay ethylene terminal would be the busiest of its kind in the world).

The facilities were planned in connection with the exploitation of the Brent field in the North Sea, where large quantities of both dry and associated gas are found. Rather than flaring, reinjecting or use by British Gas at St. Fergus, it is considerably more resource efficient and more



1a. Location of Mossmorran



1b. Mossmorran and Braefoot Bay in relation to residential areas

Figure 1

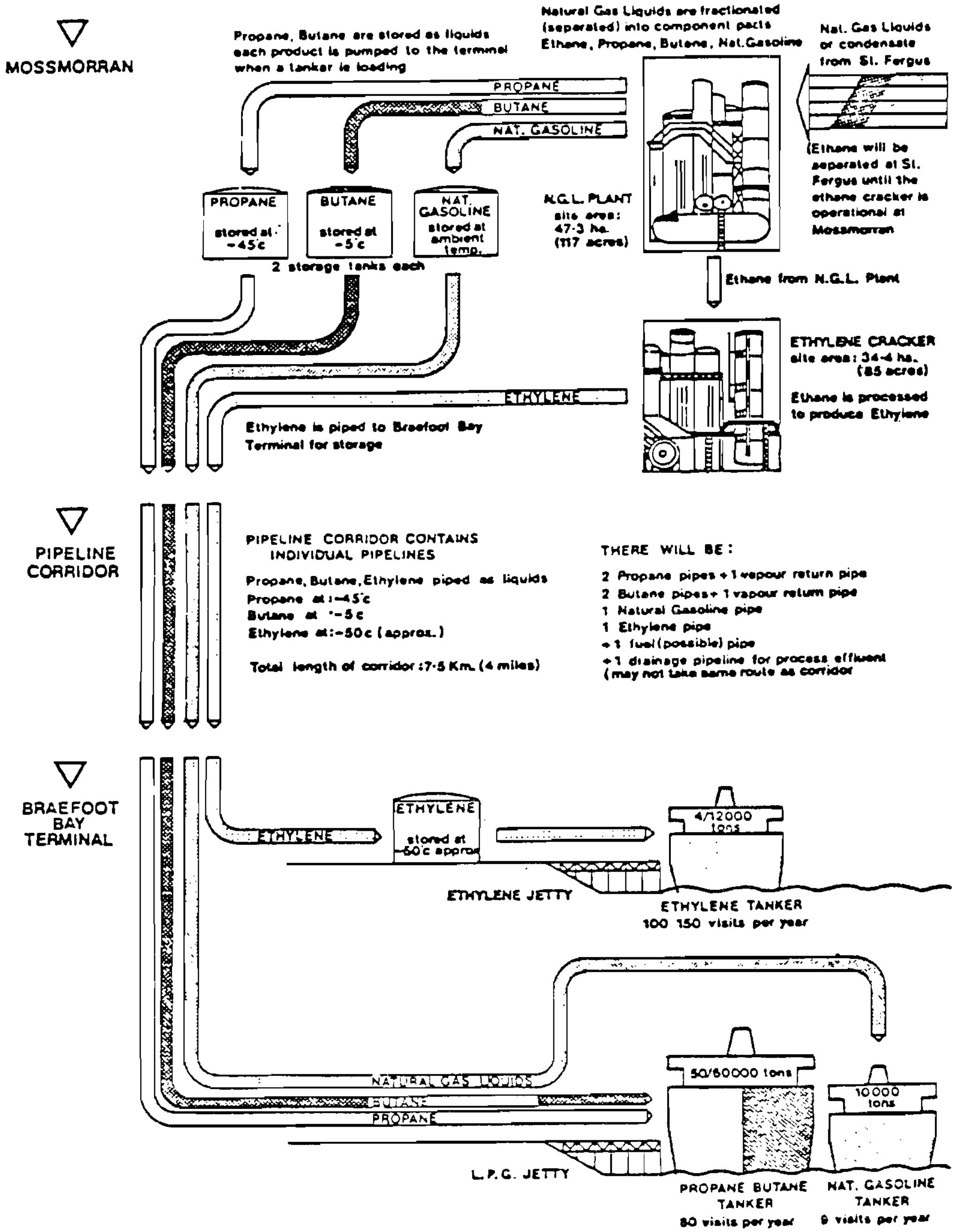


Figure 2: How the plants and terminal would relate
Source: Fife, Kirkcaldy and Dunfermline District Councils 1977.

profitable to sell the commercially used derivative gases, propane, butane and ethylene (hence the need for the Mossmorran plant) to contracted customers in Europe and the United States. These sales had been agreed to begin in October 1980.

The facilities have prompted long and emotional debate on issues of safety due to their hazard potential and planned proximity to residential areas. Dalgety Bay (5,000 population) and Aberdour (2,000 population) are each within a mile of the proposed Braefoot Bay terminal, Cowdenbeath (10,000 population) is about a mile away from the Mossmorran site.

The hazard potential of l.e.g.s is now well documented in the literature (Davis 1979; Gugan 1978; General Accounting Office 1978; Health and Safety Executive 1977, 1980). An accidental release of gas threatens fire or explosion, depending on the ignition source, the degree of mixing with air and the degree of containment of the cloud. Leaked gas will drift downwind until a source of ignition is found (open flame, stray electrostatic spark) or until it is dispersed below its lower limit of flammability. Safeguards in the l.e.g. industry are based on plant design aimed to minimise the threat of leakage, safety systems to ensure any leakages will be 'small', and good manning practices. Numerous incidents involving l.e.g. storage, loading and trans-shipment facilities have occurred (see reference cited earlier) notably at San Carlos, Spain in 1978 when a propylene truck exploded on its way past a holiday campsite, and at Qatar, Saudi Arabia, when a modern gas fractionation plant exploded, devastating the surrounding area.

3. THE INSTITUTIONAL FRAMEWORK

> "There has been a deplorable loss of confidence in Public Inquiries" (Lord Denning, September 1979)

Lord Denning's statement reflects a growing dissatisfaction with the public inquiry system, and widely voiced criticism of it, stemming from repeated uses of public inquiries for purposes for which they were not designed and issues which they are inappropriate to handle (Sieghart 1979; Pearce, Edwards and Beuret 1979; Edwards 1980; Rowan-Robinson 1980). In the opinion of the author, the Mossmorran-Braefoot Bay Public Inquiry emerges as a further exemplification of such criticism. Criticism may be based on several counts with many classic issues emerging from them.

It would appear from the report of the proceedings that the Inquiry was used in part to debate issues of technical complexity and even uncertainty. The suitability of using a public Inquiry for this purpose has been questioned elsewhere (Breach 1978, p. 157; Sieghart 1979, p.7) and in the Mossmorran-Braefoot Bay case this changes from being a general procedural criticism to a substantial cause for disquiet on the recognition that these technical issues carry profound implications for public safety. Thus, sworn evidence, cross examination and re-examination may be appropriate for determining the course of past events in a court of law, but hardly for weighing up likely consequences of future uses of technology with a view to pronouncing them as 'safe' (whatever this means—see below). The Planning Inquiry Commission was designed to avoid exposing local Planning Inquiries to such criticism, a commission of 3-5 suitably qualified persons with adequate resources and powers to carry out in depth study and call, where appropriate, for specialist research or advice. Its position as a famous white elephant on the statute books is renowned (Sieghart 1979; Pearce et al. 1979).

A second germ of dissatisfaction in the Mossmorran-Braefoot Bay case was that various persons and institutions who in their different capacities might have been expected to serve the interests of the public, did not always enjoy their confidence. This applied to local councillors, the local planning departments and the Health and Safety Executive. It has been remarked elsewhere that in advising on hazardous activity (Council for Science and Society 1976, p. 43), health and safety inspectorates have tended to behave paternalistically, consulting with those who impose risks, while considering those who experience them as passive partners. Individuals living in the vicinity of the proposed installations (later to become the main opponents of them) soon resented their role as passive partners when one of their number voiced his own opinion about the scale of the hazard potential that could be involved. This initial loss of confidence between the public and the Health and Safety Executive (the body with statutory responsibility of safeguarding the public against injury or death from industrial activity), was not to be regained; indeed it intensified into a bitter struggle. A remark made by the chairman of the objectors Action Group in a letter to the *Scotsman* (15 August 1979) exemplified this discontent "The actions of .... the Health and Safety Executive appear to have been designed to conceal facts rather than to elucidate or to promote genuine consultation."

Whether or not this loss of confidence can now be viewed as being legitimate will be considered later. The immediate consequence was that public local objectors at the Inquiry entered a debate on complex technical issues in order to highlight the hazard potential of the proposed installations and raise aspects of their own safety which in their view would otherwise not be adequately considered. The loss of public confidence was not confined to the Health and Safety Executive, but also related to local, district and regional councils (Fife, Dunfermline and Kirkcaldy) whose conviction in the employment benefits of the proposed installations appeared to the objectors to make them impervious to important but contrary considerations of public safety.

Thus, members of the public at the Inquiry found themselves matching their expertise, time and financial resources against those of the oil companies (the proposers of the developments), the Health and Safety Executive, and the private hazard consultants of what, in their view, were hostile local authorities. Although objectors' expertise necessarily carried a handicap of lacking the detailed inside knowledge of other parties in the proceedings, it was in terms of time and resources rather than expertise that their case was felt to suffer most--petro-chemical engineers, industrial managers, accountants, lawyers, health and employment experts being amongst their number, in addition to retained consultants in fire hazard. Time became critical in a pre-Inquiry period in which unknown details of the proposer's case and a lack of specific awareness of the crucial issues at stake must have played a part, reflected during the Inquiry in insufficient time to digest the arguments advanced (again a point raised in a wider context in Sieghart 1979). The significance of the time dimension is even more critical on recognising that alone in the parties represented at Public Inquiries, public objectors work in "spare time" (for all others it is part of their paid employment). On the question of resources, a parallel mismatch may be identified--in the Mossmorran-Braefoot Bay case a comparison in financial resources may be made between those available to multinational oil companies on the one hand, and those raised through jumble sales, coffee mornings, and voluntary contributions on the other. A passage by David Lock, quoted by Breach (1978, p.157), reflects this issue, again in a wider context:

> "... enough is known to confirm that there is a very unequal distribution of resources amongst participants at many public inquiries, which leads to an unequal presentation of the various arguments and, as a result, may distort the judgement of the Inspector or, in the small number of cases that reach him, the Secretary of State. When the cost of technical advisers plus their disbursement ... are added together with loss of earnings caused by attendance at prolonged inquiries, a total of several thousand pounds can easily be incurred by an ordinary group. Win or lose, there is no provision for them to recoup any of their expenditure, regardless of the contribution they have made at the public inquiry."

A further classical quarrel concerns the nature of the consultation process of which the public inquiry is a part. At pre-Inquiry meetings between the developers, the local authorities and local residents, unequal standing between the last and the first two parties was implicitly assumed. The inquiry proper would be the only opportunity for full, open scrutiny of issues of safety. In addition to the severe limitations of the public inquiry system already noted above, three further issues can be identified here. Firstly, there would be no opportunity for any open debate of extra conditions that may be imposed on the developers (thus, the public may have cause to be suspicious of their effectiveness in improving "safety," or their assurances about making risk acceptable, or whatever). Secondly, there may be no opportunity of open debate of any additional safety evidence that may be brought to light in the intervening period between the closing of the Inquiry and the final decision (it was claimed there was plenty of this). Thirdly, there would be no opportunity for open public scrutiny of the safety audit that the operating companies were to prepare prior to commissioning of their plant.

Thus, it may be argued on several counts that the process of consultation between developers, local authorities and their advisers, and the local community was inadequate. "Only in response to a series of court actions, legal threats and public exposure has limited information been grudgingly disclosed from time to time" (*Scotsman* letter, 15 August 1979).

The issue of alternative sites for the proposed developments produces further cause for criticism. Again it is an issue raised elsewhere in relation to Public Inquiry inadequacies in general. Both the Inquiry Reporter and the Secretary of State have commented that nobody put forward viable alternative siting proposals. Given local authority consent to the present site and the considerable cost of carrying out detailed surveys on marine, geographic, topographic and socio-economic characteristics of alternative sites it is hardly surprising that the oil companies were unwilling and the local objectors unable to pursue alternative proposals in depth. Furthermore, it was plainly beyond the terms of reference of the Mossmorran-Braefoot Bay Public Inquiry to pursue the matter. It is again a point which favours the Planning Inquiry Commission rather than a Public Inquiry for these developments. It is thus difficult to judge whether there exists a feasible alternative site which would meet some well defined criteria of acceptability of risk.

In addition to the two arguments that have so far been raised (that of alternative sites, and that of issues of technical complexity) which favour a Planning Inquiry Commission rather than a Public Inquiry for these developments, a further argument could be based on the observation that the exploitation of the U.K.'s North Sea oil and gas fields is a national and not a local Inquiry by an Esso representative is to be accepted, namely that "...there is overwhelming evidence to the effect that Braefoot Bay is the *only* suitable site for the marine operations proposed" then the Mossmorran-Braefoot Bay decision could be a crucial one for the development of the Brent field.

Safety emerged as the prime issue for debate only as the Fife Inquiry proceeded, (there was also fervent objection on noise, environmental, agricultural and historical grounds) and its inadequate resolution stimulated increased opposition activity after the closing of the Inquiry. Before giving fuller consideration to aspects of safety, a summary of activity in the pre-, inter- and post-Inquiry stages will serve to provide a fuller background to the issues involved.

Pre-Inquiry

Fife Regional, Dunfermline and Kirkcaldy District Councils were initially approached by representatives from Shell and Esso in July 1976. This followed an abandonment the previous month of a Public Inquiry into the siting at Peterhead of the fractionation plant now destined for Mossmorran (Peterhead had been abandoned due to occasional freak conditions in the harbour there which made it unsuitable to handle ships with hazardous cargoes). Options for land in the Mossmorran-Braefoot Bay area were negotiated, and the local authorities involved were persuaded of the net benefits to the area, mainly additional employment in what was an area of relatively high unemployment[1]. Mossmorran had already been designated as a greenfield site preferred for industrial development (Scottish Development Department 1979). A series of public meetings were arranged by the oil companies and the local authorities in order to inform local communities of the planned developments. The local authorities adopted a favourable view of the proposed developments and two reports were issued through the offices of the local authorities. The first was a general assessment in terms of economic, land-use, visual and environmental impact, prepared through their own offices (Fife, Kirkcaldy and Dunfermline Councils 1977). The second was a report on the hazard and pollution implications of the plant, commissioned from the firm of private consultant chemical engineers, Cremer and Warner, well renowned and with considerable experience in industrial hazard assessment. The Cremer and Warner report was not a comprehensive quantitative hazard assessment but a less than exhaustive appraisal of various hazard characteristics of the proposed developments (preoccupied with hazard within the site boundaries), with some recommendation for modification in plant layout in the interests of safety. A much referred to statement from their conclusion was that

[1]See Appendix for arguments which dispute the claimed employment benefits.

> "... in the consultants' opinion, there is no reason to doubt that the installations proposed for Mossmorran and Braefoot Bay cannot be designed, built and operated in such a manner as to be acceptable in terms of environmental impact and community safety ... provided that relevant and adequate safeguards are agreed and ensured."

Faced with such a statement it is hardly surprising that the local authorities were less than convinced by contrary statements on safety being advanced by the local residents' Action Groups. However, the authorities' position in this respect is more difficult to reconcile when seen in the light of a further statement made in the Cremer and Warner report which they otherwise endorsed completely, namely that "the criteria of acceptability of risk must be set by the community at risk and not handed down as technical statements", as the Action Group apparently found wide support among the community at risk.

At the same time as the two local authority reports were being prepared opposition to the proposals began to be articulated: ratepayers and residents associations in Dalgety Bay and Aberdour combined to form an Action Group to coordinate opposition to the developments. Their main objective was to mount a convincing case of opposition at the Public Inquiry that was to be convened in June 1977.

The Public Inquiry

This sat between 27th June and 21st July 1977; the Inquiry Reporter was A.G. Bell, Deputy Chief Reporter, Scotland. The main parties represented were:

For the proposals:

Shell U.K. Exploration and Production
Esso Chemical Limited
Fife Regional Council
Dunfermline District Council
Kirkcaldy District Council

Against the proposals:

Aberdour and Dalgety Bay Joint Action Group
Donibristle Investments Ltd (Developers of Dalgety Bay New Town)
Gray Park Tenants Association
The Conservation Society
Various Yachting Interests
About forty individuals

"Independents":

The Health and Safety Executive
Cremer and Warner
The Forth Ports Authority
Representatives of local political parties

The hazard considerations spoken to by Shell and Esso included features of design, construction, inspection, operation and maintenance, and also hazards that might arise in certain specified circumstances. No comprehensive quantitative assessment was offered, as there was said to be insufficient detail at the outline planning stage for the full fault tree analysis that would be required. Statements made were thus based on evidence gleaned from incidents at similar plants elsewhere, theoretical and laboratory models that had been studied and tested and general operating experience both of their own and other companies' installations.

The independent judgements of safety factors by Cremer and Warner and by the Health and Safety Executive were in a similar vein, though with some disagreement on aspects such as the spacing of tanks and height of bunding: these represented trade-offs in detail that were difficult to balance rather than matters which would critically affect the acceptability of the plant.

It has been mentioned that Cremer and Warner were involved in the Inquiry in their capacity as independent hazard consultants retained by the three local authorities. The Health and Safety Executive were involved due to their role as statutory safety watchdogs of potentially hazardous plant and advisors to other statutory authorities involved (though not to local communities at risk). It is accepted that the plant operator takes the overriding responsibility for plant safety, though once built the Health and Safety Executive may serve an improvement or a prohibition notice if a defective or suspect system or item of the plant is observed. At the time of the Mossmorran-Braefoot Bay Inquiry the Health and Safety Executive agreed with the view that there was no reason in principle why an acceptably safe plant could not be constructed. They intended to assess the operators own full hazard assessment once the plant had been built and was operational (prior to commissioning).

The statutory responsibility for safety of the Health and Safety Executive was said to end at the loading arm on the Braefoot Bay jetty, marine safety being the responsibility of the Forth Ports Authority (F.P.A.). The F.P.A. spoke to pilotage practices, bunkering, jetty personnel and interference of the proposed installations with pleasure craft. No critical difficulties were foreseen.

Statements relating to hazard made by local authority representatives added little to that available in the Cremer and Warner report, thus agreeing that the plant would be acceptably safe. Since the statutory safety body (the Health and Safety Executive) had concluded as much, this perhaps lends further support to their lack of consideration of safety issues that might be raised by local residents.

The main case of local opposition through the Aberdour and Dalgety Bay Joint Action Group was presented by Professor Rasbash and Dr. Drysdale, from the Department of Fire and Safety Engineering at Edinburgh University. A number of points were raised over and above those previously considered, and involving some disagreement with the Cremer and Warner evidence on the movement and explodability of an accidental release of l.e.g. vapour. This disagreement was not resolved conclusively although the inspector's closing comments chose overwhelmingly to support the view of the proponents rather than the objectors by stating that "the weight of evidence suggests that the maximum credible spill is less than the quantity required to result in an unconfined explosion."

Concern was also expressed over the lack of a comprehensive quantitative assessment of hazard at the Public Inquiry stage of the Fife decision. It was felt that this was something that could and should have been done at the planning rather than the commissioning stage, because it was only in relation to such an assessment that the acceptability of the risk involved could be adequately debated. At the Public Inquiry Professor Rasbash and Dr. Drysdale were not convinced that design and operation standards alone could ensure an acceptable level of risk. With the obvious exception of other opponents to the plant, this was not a view that found any sympathy either with the oil companies (who maintained absolute confidence in their own safety assurances, and repeated that the hazard assessment being demanded was impossible to carry out at the planning stage-due to lack of specific detail), the Health and Safety Executive (who considered the hazard assessment to be undertaken by the companies themselves at the time of commissioning quite adequate), the Inspector, or other parties at the Inquiry.

A review of speeches made by others in opposition to the plant leaves no doubt about their misgivings in relation to assurances on safety that had been given. Some individuals ventured to offer constructive suggestions on alternative layout of plant in addition to voicing disquiet on the hazard assurances they had heard, but all were dismissed. Others repeated their request for a Planning Inquiry Commission to be set up.

The Inspector had little hesitation in recommending that outline planning permission for the proposed developments should be granted. A wide range of planning conditions were to be stipulated. There had also been some hesitation about the possible rehousing of the inhabitants of Gray Park, a council estate a few hundred yards from Mossmorran, and of St. Colme House, a substantial private dwelling at a similar distance from Braefoot Bay.

The Inquiry Report was submitted to Bruce Millan, the Secretary of State for Scotland, for his final decision.

Post-Inquiry Activity

The closing of the Public Inquiry proved to be a relatively early event in the Fife decision process. Unknown at the time there was to be a delay of more than two years before the decision to allow the developments was announced. The delay may have been an expensive one for the developing companies, in view of their earlier stated urgency to have the facilities operational by the winter of 1980/81.

The delay led to speculation that the oil companies might abandon Mossmorran and seek an alternative location on the Cromarty Firth. Although Mossmorran-Braefoot Bay was said to be preferable in terms of labour availability and proximity to export markets, Cromarty would be unlikely to produce the same stubborn opposition from local objectors. Indeed the level of opposition encountered in Fife on issues of technical complexity must have been a surprise as well as an irritation to the oil companies.

The objectors, profoundly dissatisfied with their public servants and officials, renewed their case of opposition through the activities of the Action Group. Events elsewhere following the Inquiry seemed to confirm their worst fears about the inadequate appraisal of hazard that had been given, and served to attract wider interest in their cause, for example:

(1) In April 1978 a modern gas fractionation plant at Ab Qaiq in Saudi Arabia exploded, devastating the surrounding area. This represented the second explosion at such a plant within a period of twelve months, an earlier explosion having occurred at Um Said in Qatar where a modern gas plant had exploded less than

two years after commissioning, laying waste the surrounding area up to a radius of 2 miles. Due to the proximity of Cowdenbeath, a corresponding explosion at Mossmorran would lead to a disaster of unimaginable proportion. The Mossmorran design was said to be impossible to allow another catastrophe stemming from the same cause (by providing fully redundant secondary storage walls), but to the Action Group this difference in design reflected no more than a practice of responding to events rather than shaping (in this case, avoiding) them; the removal of one cause of catastrophe, was not a guarantee that there would be no others.

(2) In July 1978 in San Carlos, Spain, a road tanker carrying liquefied gas (propylene) exploded on its way past a holiday campsite incinerating 200 people, the most vivid and tragic illustration in recent years of the hazard potential of l.e.g. The cause is still disputed, and the incident provides a classic example in the field of l.e.g. technology of the occurrence of an impossible event. Another road tanker disaster occurred in Mexico in the same year.

(3) Less dramatic but nevertheless disquieting was the discovery, on commissioning of a liquefied gas storage tank at Abu Dhabi in October 1978, of leaks in both main tanks. Other explosions are cited in Gugan (1978), Davis (1979), and Health and Safety Executive (1980).

(4) Events elsewhere in the oil industry provided further evidence that major accidents are far from being isolated, improbable events:

- the Ekofisk disaster in the North Sea, caused by a "fail safe" valve which had been installed upside down.
- the ecological disasters caused by major oil spills, from the Cristos Bitas, Eleni V and Amoco Cadiz oil tankers;
- the explosion of the Betelgeuse at Bantry Bay;
- the collision into the jetty at Sullum Voe of the first tanker to use the facility;
- minor incidents at sea involving l.e.g. carriers (collision with Canvey jetty, April 1979; tanker in wrong shipping lane in English Channel, June 1978; British tanker grounded in Norwegian waters; and many more).

(5) Various reports became available in 1978 which apparently reflected a more enlightened view worldwide of the hazards of liquefied gases. The most comprehensive of these was a document issued via the General Accounting Office in the United States, the main conclusions of which stated that (i) future facilities for storing large quantities of l.e.g. should be built in remote areas; (ii) facilities already in other than remote areas should not be permitted to expand and their safety should be re-evaluated; (iii) storage and transport of l.e.g. poses serious dangers to the public.

(6) A quantitative hazard assessment which had been commissioned by the Health and Safety Executive on the Canvey Island liquefied energy gas facilities was issued, recommending that two l.e.g. terminals (smaller than that proposed for Braefoot Bay) be moved to a distance of 4 km from the nearest housing area rather than the 1 km that had originally been planned. Although this report had been officially heralded as a major breakthrough in the U.K. in hazard control policy, and had been claimed (in a statement to parliament by Guy Barnett) to prove the Government's determination to show that important planning decisions should be taken in the full knowledge of all the implications for those likely to be affected, a similar hazard assessment for the Mossmorran-Braefoot Bay development was steadfastly refused at the planning stage.[2]

(7) Practices elsewhere in the world also confirmed a more enlightened strategy--the State of California passed an Act in September 1977 which effectively banned the construction of l.e.g. terminals and the use of shipping lanes by l.e.g. tankers within 4 miles of populated areas. In the Netherlands a large l.e.g. installation is now planned for Eemshaven (25 km from the nearest population) rather than its originally designated site in Rotterdam.

[2] An official safety assessment was, however, being prepared for the St. Fergus-Mossmorran overland pipeline; see Health and Safety Executive 1979.

These observations, made by the Action Group since the closing of the Inquiry, formed a basis for their call for a reopening of the Inquiry.

Their case was substantiated further by way of their own partial quantitative assessment of hazard in a report entitled "Shipping hazards." In the absence of an official report of this nature, the Group produced their own, and, in order to avoid any criticism of amateurism or bias submitted it for scrutiny to the independent firm of consultants Burgoyne and Partners. With only minor qualification the findings in the report were accepted by this firm. They bear repetition here (see Table 1), as until refuted, they establish beyond doubt the view that the planned terminal at Braefoot Bay would pose an unacceptable level of risk to the local population–most alarmingly in Aberdour and Dalgety Bay, and with other communities being affected to a lesser extent.

"Shipping hazards" and all other post-Inquiry information summarised above was presented to the Secretary of State for Scotland. None was accepted by him as relevant additional evidence. In addition, number of points on which evidence on hazard at the Public Inquiry was considered to have been seriously erroneous were identified. Again these points were not considered to be relevant.

A further submission by the Action Group concerned the risk posed by break sparks from radio sparks or electro-magnetic radiation which can create a hazard of ignition or explosion at gas installations. The Group claim that there are quite extensive military radio and radar transmissions in the Firth of Forth. This hazard had not been considered at the Inquiry either by Shell and Esso or by the Health and Safety Executive. It was accepted as relevant additional evidence, and further official

Table 1. Risk Assessment: Braefoot Bay Berthing Facilities

Location	Distance from Jetty (km)	Risk of Multiple Fatalities Per Year*
Aberdour	1	$1{,}000 \times 10^{-6}$
Dalgety Bay	1	$1{,}000 \times 10^{-6}$
N. Queensferry	5.6	11×10^{-6}
S. Queensferry	7.2	89×10^{-6}
Hound Point (Dalmeny)	4.5	13×10^{-6}
Cramond	6.1	37×10^{-6}
Granton	7.6	37×10^{-6}
Leith	9.8	19×10^{-6}
Burntisland	5.3	148×10^{-6}

*An acceptable level is generally agreed as being one in a million per year.

Source: Aberdour and Dalgety Bay Joint Action Group (1979); results verified in a private consultant's report.

research by the Health and Safety Executive in this areas was duly demanded. It is this research that made the greatest contribution to the long delay between Inquiry and decision; it did not ultimately affect the way the decision eventually went.

The delay served to give wider publicity to the issues that the Action Group were fighting. Newspapers (notably the *Scotsman)* carried a steady stream of articles and letters, and occasional television documentaries reflected aspects of the fight. Lothian Regional Council, an authority to the south of the Forth and not hitherto involved with the developments, pressed for a reopening of the Inquiry due to the hazard posed by l.e.g. traffic in the Forth *(Scotsman*, 9 September 1979). The South of Scotland Electricity Board are reported to have re-evaluated the resilience of the proposed Torness nuclear power station (25 miles away from the jetty at Braefoot) again due to potential hazard of explosion. Support for the Action Group cause was also forthcoming from the academic community, notably Professor James Fay from the Massachusetts Institute of Technology, and renowned in the field of l.e.g. hazard. In his view the proposed developments were far too dangerous to site in such close proximity to large residential areas.

Support locally was also strong. The Group had long claimed such support, and it was something of a test of this claim when they put up a last-minute candidate for the Regional Council elections held in May 1978. After less than a week's canvassing for a candidate hitherto unknown in four out of the five communities in the ward, the Action Group noted that their candidate polled 50% more votes than the Labour candidate and lost by only three votes to the sitting Conservative councillor.

A change of national government in June 1979 gave the Action Group new hope that the mass of additional evidence that they had assembled would be examined by the Secretary of State for Scotland before taking his decision. Representatives of the Group were invited to Westminster on 13 June 1979 to present their case.

The outsider watching events can only speculate at the nature of consideration that the additional evidence was given--whether it was a shallow, token response, or a genuine appraisal. The decision of approval to be announced by the Secretary of State for Scotland may be portrayed in various ways: as a calculated gamble on criteria of public safety; as a deliberate whitewash of objectors' arguments in the face of the threat from developers to abandon the project completely; as an overdue termination of a public participation exercise that had gone too far; as vindication of the aims and assurances of the developers and local authorities.

4. THE ACCEPTABILITY OF RISK

> "Leaving the judgements of acceptability to the experts will not necessarily guarantee either fair decisions on risks or effective control of them" (Council for Science and Society 1976, p. 31).

Such words appeared to have no place in the Fife decision. There was no question but to leave such judgements to the (officially appointed) "experts," and their apparent failure to use the phrases "acceptable risk" or "acceptably safe" in a meaningful or consistent way does little to command public confidence or respect. It is appropriate here to consider the criteria on which judgements of acceptability were based.

It was said on occasions by all main parties (the oil companies, the Action Group, Cremer and Warner, and the Health and Safety Executive) that an acceptable degree of risk was such that a dangerous incident which could cause injury to a member of the public outside the boundary of the plant should not occur more than once in a million years. This is a classic yardstick of acceptability (Council for Science and Society 1976; Health and Safety Executive 1980) and although it may appear to provide a scientific foundation to hazard appraisal, it does not possess any meaning in the context of Mossmorran-Braefoot Bay Inquiry because no quantitative assessment of hazard had been made. Thus, what is an apparently comforting "one in a million" possibility can only be regarded as an empty statement, in the Fife context, to which nothing else that was said may be directly related. In their own report (Fife, Dunfermline and Kirkcaldy Councils 1977) the local authorities had stated:

> "Had it been the case that the evaluation carried out by the consultants Cremer and Warner had shown that any aspect of the proposals would constitute an unacceptable level of risk to life and property there would be no alternative to recommending refusal of the applications."

On the one in a million criteria, the results in Table 1 undoubtedly confirm an unacceptable risk; and yet there was no substantial response to these results.

The other yardsticks of acceptability that were used were still less meaningful than one in a million. The meaning of the frequently used word "safe" is not self evident. In the report by Cremer and Warner (1977) safety is defined in the following terms: "an activity is said to be safe if the associated risk and consequences, considered together, are regarded as acceptable," but other parties were not bound by this definition (nor did they refer to it). The Council for Science and Society (1976) prefer the more rigorous phrase "a thing is provisionally categorised as safe if its risks *are deemed known and in the light of that knowledge* judged to be acceptable." It is reasonable to conclude that at the Fife Public Inquiry the word "safe" was used less than rigorously. Both definitions fall back on the notion of acceptability, which itself needs to be defined. This might be approached by invoking the classic yardstick of acceptability of the "one in a million" possibility, but this in turn requires that the Mossmorran and Braefoot Bay hazard is quantified so that it can be related to this yardstick. Alternatively, acceptability might be approached by asking who should judge it rather than how it should be judged. Thus, if the community at risk judges the risk as acceptable then this may lead to adequate resolution of the problem. This was apparently the course advocated in the Cremer and Warner report, in their statement already quoted above that "the criteria of acceptability must be set by the community."

This statement, however, was not pursued in depth. It is worth considering the notion here, nevertheless. Risk may be deemed acceptable if accompanied by benefits that are perceived to outweigh it. This could not be concluded in the Mossmorran-Braefoot Bay case, however, where the Inquiry Inspector stated that there would be a few local benefits from the project. A more dubious way of resolving the issue would be to invoke the belief that "the extreme case of an accepted risk is one that is totally unknown" (Council for Science and Society 1976). Thus, by remaining ignorant themselves and assuming that the local communities were similarly ignorant, it would be genuinely possible (though hardly reassuring) for the local authorities to pronounce the proposed facilities "acceptably safe."

The question of who should judge acceptability also bears further consideration. There would appear to be five possibilities. It could be left to the industry operating the installations--the Advisory Committee for Major Hazards (Health and Safety Executive 1976, 1979) argues that the prime responsibility for safety should lie with industry, and the Inquiry statements made by Shell and Esso appeared to bear out this view, almost to the point of arrogance, with repeated references to their safety consciousness. While accepting that it is not in industry's interest to operate unsafe plant, it is also true that safety is not their primary objective. Reassurance from a more independent party is more likely to convince a sceptical public.

Judgement by the Health and Safety Executive (given the necessary increase in resources) or some other independent body appointed through the local authority or other public sector institution may alternatively be more convincing. This is unlikely to be satisfactory unless they enjoy the public's confidence to a greater extent than was the case for the Fife decision.

Judgement by some third party appointed by (or at least known to be given standing by) the community at risk may provide a more credible result.

It could alternatively be left directly with the community at risk, as remarked elsewhere in this paper.

Finally, a single Inspector at a Public Inquiry, judging the evidence presented to him, could make the telling pronouncement on acceptability. It has been argued (Sieghart 1979) that with a major project having complex, controversial and long-term implications, an impossible burden is placed on a single person, and the credibility of the result is reduced.

The gremlin in all cases is the catastrophic event (a massive escape of gas, a terrifying explosion, a vast fireball) whose probability of occurrence is very low. Even if a quantitative assessment of hazard had been made at the Inquiry stage, and the associated probability of occurrence calculated as negligible (10^{-6} or below), it is still open to question whether the community at risk would accept the installations as being effectively safe" (suspicious that all possible causes of hazard had not been adequately accounted for). No amount of calculation, reassurance or additional safety practices are necessarily absolutely convincing. Ill defined hunches, or the more rigorous identification of "impossible" events that have occurred in the past (San Carlos, Flixborough) spoil the attempt. Human fallibility will always be open to exposure.

> "85% of industrial accidents are the result of human failure. Even the most reputable and safety conscious companies are vulnerable to major disasters and contribute to the total of industrial accidents" (Public Inquiry, Findings of Fact).

In Popper's words

> ".... even the greatest improbability always remains a probability, however small, and consequently even the most improbably processes, i.e., those which we propose to neglect, will some day happen."

It is not the contention in this section that the statutory production of a quantitative hazard assessment at the outline planning stage will resolve the issue of acceptability, merely that it will put it on a sounder footing for meaningful public debate at this stage. (Even though the planning permission sought at this stage is termed "outline," this effectively takes the role of "final" permission in most cases.) The impressive General Accounting Office report (1978) concludes as much.

> "Risk assessment studies have not reached a stage where they give confidence in their conclusions. Therefore, safety decisions cannot logically be based on them."

It is inappropriate to take this as an excuse for making no attempt to quantify risk; it suggests rather that due account be taken of the confidence limits of such risk assessments, erring in the interest of safety towards the most pessimistic of possible outcomes (apparently the case with the Canvey report).

Two other factors arising in the Fife decision deserve comment in discussing the acceptability of risk.

The question of sabotage was given superficial treatment at the Inquiry. It was recognised by the operating companies that it is almost impossible to safeguard installations against sabotage and terrorism, and although the point was seized by individual objectors, it was not pursued in any depth and was not even mentioned in the Inspector's own conclusions or recommendations. Yet the ease with which such installations may be entered has been demonstrated on several occasions, and appears to undermine completely assurances that the installations can be made acceptably safe.

The final aspect is that of a cordon of safety around a major hazard installation. Its specification as a zone within which residential development is not permitted would appear to be a prudent precaution. The most striking feature in this respect for the Fife facilities is that although Mossmorran was so designated, the Braefoot Bay shipping terminal (due to handle millions of tons of l.e.g. annually, and said to be the most vulnerable part of the Fife development) was not.

5. REVIEW

> "Calamities leave one with a sense of insecurity; they do not happen often, but happen they do, and since they are unaccountable one wonders why they do not happen oftener, and to whom one will happen next" (A.S.F. Gow, Letter from Cambridge, 1940; see Gow 1945).

It is understandable that quiet, respectable communities such as Aberdour and Dalgety Bay may be hostile to planned petro-chemical installations, that will produce a lasting scar on a peaceful coastline, affect the local ecology and intrude on places of local historic interest. It could be argued that the issue of safety, considerably more emotional than these others, was being used by the objectors as the main weapon with which to fight all aspects (not just hazard) of the proposed developments, so as to leave their corner of Fife free from any such development.

The fight was mounted by the middle class intellectuals of Aberdour and Dalgety Bay, and not by the blue collar workers and unemployed from Cowdenbeath, and yet this latter community will be at a similar distance from a proposed major hazard installation. Thus, again there may be grounds for scepticism about the motives of the Action Group. The nature of the battle, however, turned out to be such that it could only have been mounted by members of the public with the resources of the middle class (including a high standard of education). The battle was fought on matters of technical complexity, and the issues that were raised can and should be divorced from socio-economic characteristics of the people who were raising them and given adequate response from public servants (the Health and Safety Executive, the Secretary of State for Scotland, the local authorities) in their own right. Such response was not apparently forthcoming.

The objectors might be forgiven for thinking that a campaign mounted on more frivolous grounds would have brought them more success. Unorthodox theatricals and deliberately disruptive tactics command wider coverage by the media and have been known to prompt public officials into a more appropriate state of awareness. In the case of the opposition in Fife, however, intellectual argument prevailed over such possibilities. Furthermore, it was a campaign conducted from the beginning through local residents associations, and although it attracted later support from, for instance, the wider academic community, it remained independent of the more powerful environmental movements such as Friends of the Earth. The opening of the Windscale Inquiry just two weeks before that at Mossmorran was not the most fortunate coincidence of timing for the objectors in seeking more widespread publicity for their cause. An investigation by Pearce, Edwards and Beuret (1979) accompanied the latter Inquiry with a view to identifying the major weaknesses in the institutional procedures available. It is a pity that the exercise was too late for the Mossmorran decision.

6. CONCLUSIONS

> "The sense of fairness is deeply ingrained in our traditions. In this country most people will readily accept decisions that are adverse to them, provided they have been reached by procedures that are seen to be fair" (Sieghart 1979, p.4).

An attempt has been made in successive sections of this paper to review the main areas over which disquiet about the Fife decision appears warranted, and by which its fairness can thus be questioned. Institutional deficiencies have been discussed, a marked inadequacy in consideration of acceptability of risk has been identified, and specific points of erroneous evidence have been hinted at. In addition to these areas, a further criticism, which finds agreement between all main parties, concerns the excessively long period of time over which the decision spanned. Since the areas of disquiet aspects of safety were responsible or the delay, it would be more acceptable if the delay had enabled some reassurance in these areas, but this was not so. It is left to note possible improvements in order to enable the next such decision to be made on a more satisfactory basis--either to render public participation less of a mockery, or (since the Cromarty area in which the next major gas plant is destined is unlikely to present anything like the determined and skilled opposition aroused by the Action Group from Aberdour and Dalgety Bay) to ensure the decision process is seen to be fair on a wider national basis.

Remedies for institutional deficiencies in the public inquiry process have been discussed in Sieghart (1979) and Pearch, Edwards and Beuret (1979). To these must be added a regeneration of respect for and confidence in public sector institutions (both the Health and Safety Executive and local authorities) concerned with public safety. It is not sufficient for local authorities to rely completely on the advice of independent private consultants in this respect; it would not be the role of such consultants to define criteria of acceptability of risk, but rather to advise whether such criteria are met in any given context.

Criteria of risk acceptability must be identified and used consistently throughout the decision process. Agreement is needed over whether and at what stage in this process a full quantitative assessment of hazard needs to be produced, who should produce it, and who should be the final arbiter of risk acceptability, bearing in mind that respect from all main parties to the decision is needed to ensure credibility. It should, moreover, be possible to accommodate at any time additional evidence to remedy any serious deficiencies or omissions in hazard appraisal that emerge during the process.

Physical and economic attributes of sites suitable for l.e.g. installations are considerably easier to define than those referred to above. This does not mean that they are more important.

REFERENCES

Aberdour and Dalgety Bay Joint Action Group. 1979. *Shipping hazards*. (mimeo).

Arguile, R.T. 1980. "Was the Beaver Inquiry a Waste of Money?," *The Planner 66* (5), p.115.

Breach, I. 1978. *Windscale Fallout*. Penguin.

Cope, D. and P. Hills. 1980. *The Benign Mine* Paper to the Annual Conference of the Institute of British Geographers, Lancaster.

Council for Science and Society. 1976. *The Acceptability of Risks*. Barry Rose (Publishers) Ltd.

Cremer and Warner. 1977. "The hazard and environmental impact of the Shell NGL and Esso ethylene plant at Mossmorran and associated berthing facilities at Braefoot Bay." (C1164) London.

Davis, L.N. 1979. *Frozen Fire*. Friends of the Earth.

Edwards, L. 1980. "Efficiency considerations for 'major' Public Inquiries." S.S.R.C. North Sea Oil Panel Conference, Glasgow.

Fife, Dunfermline and Kirkcaldy Councils. 1977. *An Assessment of the Shell and Esso Proposals for Mossmorran and Braefoot Bay*.

General Accounting Office. 1978. *Liquefied Energy Gases Safety*. A report by the Comptroller General to the Congress of the United States, Washington, D.C. EMD-78-28.

Gow, A.S.F. 1945. *Letters from Cambridge*. Jonathan Cape (Publishers), London.

Gugan, K. 1979. *Unconfined Vapour Cloud Explosions*. London: Institute of Chemical Engineers.

Health and Safety Executive. 1976. *Advisory Committee on Major Hazards: First Report*. London: H.M.S.O.

Health and Safety Executive. 1978. *Canvey: An Investigation of Potential Hazards from Operations in the Canvey Island/Thurrock Area*. London: H.M.S.O.

Health and Safety Executive. 1980. *A Safety Evaluation of the Proposed St. Fergus to Mossmorran Natural Gas Liquids and St. Fergus to Boddam Gas Pipelines*. London: H.M.S.O.

Pearce, D., L. Edwards, and G. Beuret. 1979. *Decision Making for Energy Futures*. Macmillan.

Rowan-Robinson, J. 1980. "Some legal aspects of the Public Inquiry." S.S.R.C. North Sea Oil Panel Conference, Glasgow.

Sieghart, P. 1979. "The Big Public Inquiry," Outer Circle Policy Unit, London.

Scotsman newspaper, 15 August 1979; 9 September 1979; 18 March, 1978.

Scottish Development Department. 1978. *Report of the Public Inquiry into the Shell/Esso Mossmorran- Braefoot Bay Proposals*. Edinburgh: New St. Andrew's House.

Scottish Development Department. 1979. *Forth Estuary Study*. Edinburgh: New St. Andrew's House.

Sunday Times newspaper. 5 May 1980.

APPENDIX

Letter to *Scotsman* newspaper -- 18.3.1978

MOSS MORRAN project 'is a job loser'

6 Seaside Place, Aberdour
Fife,
March 16, 1978

Sir, -- Recently publicity on the Moss Morran petrochemical proposals has concentrated almost exclusively on the hazards, and perhaps rightly so as evidence accumulates daily that NGL is not quite so innocuous a product as oil. However, in recent letters from Mr. Baker and Councillor Livingston, and in Maurice Baggot's article this week, the job advantages have been raised, and it is timely to remind ourselves what those job opportunities are likely to be. Most of the pronouncements appear to be unsupported guesswork; the only sound basis for discussion is evidence laid before the public inquiry, and it is from that source that I derive my figures.

First of all, the number of jobs involved. Maurice Baggot quotes 500 permanent jobs from the NGL and ethylene plants combined, and Harry Ervine, M.P. (who certainly should know better) inflated this figure to 750 on Radio 4's "All Things Considered" on Tuesday night. The applicants, Shell and Esso, were not so optimistic at the inquiry where they quoted for the NGL plant, the only proposal for which there is a permanent commitment to go ahead. 120 permanent jobs -- 80 Shell and 40 "contract" -- the latter being described as security guards, canteen workers, cleaners, etc. The 80 plant operators would be skilled men (one hopes) and would of necessity be imported into Fife. Shell suggested, by analogy with an Esso plant in Australia, that five years might elapse before local-born personnel would be employed in these areas in significant numbers.

Esso's estimate of permanent employment was 350. I have no details of the make-up of this figure, but one might expect the same sort of skill breakdown as for the NGL plant. And the same time factors for local build-up. Here, however, there is no commitment to go ahead and it is well established in petrochemical industry circles that of the four large ethylene plants under consideration in the UK only one is likely to go ahead. Why should we assume it will be at Moss Morran, particularly as Esso stressed the critical importance to them of the regional development grant, and there are now strong pressures from the EEC that such grants should be withdrawn from petrochemical developments. To a pessimist, or perhaps just a realist, then, the job picture is 40 permanent jobs in 1981 and perhaps another 40 by the mid-80s.

Secondly, Maurice Baggot quotes the job multiplier--the creation of service industries to support the actual plant jobs--as three jobs for every plant job. Shell's figure was nowhere near this, and they are hardly likely to have underplayed this benefit.

There is no doubt that the construction phase will require a substantial workforce, and if this plant does come to Fife it is to be hoped that local firms and workers will benefit. However, Shell and Esso were quite positive at the inquiry that while local firms would be invited to tender for construction subconstracts, they would receive only equal consideration with outside firms, and price, and perhaps more important, established quality and delivery performance would be the only criteria. Fife is short on experience of building petrochemical plants and is likely to be disadvantaged here. On top of this, much of the site work will be skilled, and the comparison of the unemployed register for Fife (levels as stated in one of the local authority productions to the inquiry) with Shell's requirements shows an unbalance which verges on the ludicrous:

Trade	Unemployed	Shell Requirement
Steel fixers, erectors and riggers	21	225-350
Welders	24	100-150
Plant electricians	26	200-300
Pipe fitters	27	200-300
Insulators	22	150-200

In the conventional building trade, bricklaying, joinery, painting, and labouring, there was capacity to meet Shell's needs but in the skilled trades quoted, what distortions are going to be introduced into local employment patterns by the massive shortfall, and what ancillary jobs will be lost in consequence?

Mr. Baggot quotes my own firm, Marconi, where current unfilled vacancies are in excess of 200. In particular, we have urgent openings for mechanical fitters. There were none on the unemployment register as quoted at the inquiry and presumably this is still the case: Shell want 25. If we lose part of our fitting workforce to them, and our potential sub-contractors suffer likewise, how many wiremen, testers, inspectors, progress planners, and other support jobs will go because we can no longer take on work involving mechanical fitting? But then, perhaps the workforce won't all be local, and the people of Cowdenbeath will have the pleasure of a local construction camp, and 700 to 1000 migrant workers for three or four years on their doorstep. Of what benefit is this to Fife? I note in passing that Marconi have already, since the inquiry, created more new permanent jobs than Shell offer, virtually all for local people, without any increased risk to the community or despoilation of the environment: also that if the Braefoot Bay terminal suffered a major accident, all 2400 jobs in our factories might be lost (along with the lives of the job holders) as we are about one mile from Braefoot.

One final point on employment -- the key worker. Thriving businesses depend for success and continued growth on small numbers of key specialists who can read the market right and create product ideas to satisfy that market. Such people are seldom motivated purely by money, and Fife in the past has attracted many of them from other parts of the UK by its pleasant, nonindustrialised environment. The hazard, pollution, and visual intrusion of a petrochemical plant are hardly likely to enhance such attractions. One of my former colleagues has recently been investigating sites in Fife for a new venture of his company, and he told me, and I believe also Fife's regional officials, that if the petrochemical plant comes he will not and without him, neither will 100 jobs.

The people who oppose this plant, not all of whom live in Aberdour and Dalgety Bay, are not solely concerned with their own property values. They include some of the most successful job creators in Moss Morran. They know from experience what makes employment. A sample of their experience was laid before the inquiry which could not be contested by Shell or Esso, who left employment investigations entirely to the main contractor (who was not available for examination at the inquiry), or the local authorities. The Moss Morran project is a job loser and we believe it is criminal in deluding the unemployed of Cowdenbeath into thinking that their problems would be resolved by its coming.

J. R. Sutelli

A SHORT HISTORY OF THE CALIFORNIA LNG TERMINAL

Joanne Linnerooth
IIASA

INTRODUCTION

During the last decade, three liquefied natural gas (LNG) projects were proposed for California. At this writing, Pacific Lighting Corporation and Pacific Gas and Electric Company are still seeking government permits for two of these projects, involving the import of liquefied natural gas from Indonesia and South Alaska. The third LNG project, proposed in 1974 by the El Paso Company, was to bring Alaskan North Slope gas by ocean carriers to a receiving terminal in Southern California. This proposal has been rejected in favor of an overland pipeline.

While these three projects are interrelated, this case history will focus on the Indonesian LNG project. The intent of this brief history is to outline the most important events of this decade-long controversy (for more detailed case histories, see Ahern 1978 and Western 1978). A discussion of the issues underlying this controversy follows. (See the Appendix for a Summary of Major Events Timetable.)

THE INITIAL PURSUIT OF A TERMINAL SITE

Based on projections of decreasing natural gas supplies and increasing needs, Pacific Lighting Corporation[1] began in the late 1960s to pursue supplies from Indonesia and Cook Inlet, Alaska. In 1972, a letter of intent was signed by PacIndonesia and Pertamina (the Indonesian state-owned oil company) for the purchase of LNG at the rate of about 540 million cubic feet per day. After three years of price negotiations, the LNG contract was approved by the Indonesian government.

Meanwhile, Pacific Lighting Corporation had created a subsidiary, the Western LNG Terminal Company (Western), for the purpose of planning and building two import terminals. In 1972, Western was joined by the El Paso natural Gas Company which was seeking a site to receive gas from Alaska's North Slope. After somewhat limited site screening, the Port of Los Angeles was chosen to receive gas from Cook Inlet and Oxnard was chosen to receive gas from Indonesia; because El Paso had a corporate policy of not siting a LNG facility within ten miles of a populated area, the remote Point Conception (Little Cojo Bay) site was chosen to receive gas from the North Slope.

[1]Pacific Lighting Corporation is the parent holding company of Southern California Gas Co. PacIndonesia and Western are now 50% owned by Pacific Gas and Electric Co. and Pacific Lighting Corporation.

In 1974, applications for each of these sites were filed with the Federal Power Commission (FPC)[2]. In support of the populated Los Angeles and Oxnard sites, Western commissioned two risk assessment studies (Science Applications, Inc., 1975a,b) which showed the safety risks to be acceptably low. Based upon probabilities of marine and shore LNG operations these reports generated estimates of the likelihood that members of the public would be killed during any one year from terminal operations. In the usual manner, these risks were compared to other possible causes of death including, e.g., ill health and occupational hazards. In addition, as required by federal law, environmental impact statements for both sites were prepared by the Federal Power Commission. Further, Oxnard commissioned a separate study of the environmental effects (Socio-Economic Systems undated). This study expressed the risks of the proposed project in terms of worst-case scenarios showing up to 70,000 possible casualties in the event of an accident, which "electrified" opposition to the terminal (See Ahern 1980). The Oxnard risk assessments are discussed in more detail in a later section.

In December 1977, after three years of hearings, the FPC conditionally approved the Oxnard site, but the Port of Los Angeles was rejected as a possible site upon the discovery of an earthquake fault (for a critical review of this lengthy approval process, see Western 1978). El Paso's scheme to import gas from Alaska's North Slope to Point Conception was rejected in favor of a competing pipeline project through Canada.

[2]The FPC was essentially a financial regulatory agency with a mandate to regulate pricing policies and charged with approving gas import projects. In 1977, it was absorbed by the Federal Energy Regulatory Agency (FERC) and the Energy Regulatory Administration (ERA) of the newly created Department of Energy (DOE).

A STALEMATE

The local reactions to federal approval of Oxnard and to federal rejection of the Port of Los Angeles were both encouraging and discouraging to the oil companies. The Los Angeles City Council voted that the benefits of the $155 million terminal outweighed the risks posed by the earthquake fault;[3] alternatively, the citizens of Oxnard became sensitized to the risks of the planned $300 million terminal.[4] The Oxnard public reaction, ignited by a published worst-case accident scenario, and fueled by growing disagreements among the expert community over the risks from LNG, slowed the approval process.

Though Western would have liked to defend its position at Oxnard by pointing out that the terminal would meet all standards and regulations governing terminal design and operation, the reality was that a comprehensive set of federal regulations to ensure public safety did not exist. During deliberations on these three LNG terminals, both the Coast Guard (CG) and the Office of Pipeline Safety Regulation (OPSR)[5] made moves proposing LNG terminal safety regulations. These regulations have only quite recently been made available (see US Department of Transportation 1980a,b). Because the difficult task of assuring the safe operation

[3]The explosion of the ship Sansinena in the harbor (December 1976), did shake the Council's beliefs; however, after commissioning a "thorough study," the Council voted almost unanimously in favor of the terminals.

[4]The population of Oxnard is approximately 100,000; around 20,000 persons would be living within two miles of the planned facility, but only very few people within one mile.

[5]The Coast Guard, under the Department of Transportation (DOT), exercises marine safety regulatory authority over LNG tanker construction and operators and over parts of the terminal. The OPSO, also a part of DOT, has on-shore regulatory authority. There exists a memo of understanding for these overlapping mandates.

of an LNG terminal fell on the shoulders of the nonexpert local authorities, much of the blame for the uncertainties and problems surrounding LNG terminal siting has been seen to lie with the federal agencies (Ahern 1978).

The relationships between the federal authorities and the state authorities for LNG facility approval and siting is deliberately vague. The federal government, by choosing not to clarify its mandate, has in effect chosen not to challenge state authority. In fact, the DOE has intentionally avoided a confrontation in the California case, in spite of their advocacy of the Oxnard site. Thus, though federal and local approval of a site was viewed as necessary, the final approval was vested in a stage agency--the California Coastal Commission (CCC), which was created in 1976. The CCC is composed of 12 lay people appointed from a variety of sources and serving only parttime, and has responsibility for the protection of the California coastline. After much painful deliberation, the CCC decided against siting a facility in a populated area in favor of a remote spot on the beautiful California coastline; that is, they decided "against birds and for people". In 1977, the CCC advised Western to pursue more actively the remote Point Conception (Little Cojo Bay) site.

At this point, Western faced a stalemate involving all three levels of government. On the federal level, the FPC/FERC was in favor of the Oxnard site, but the US President's National Energy Plan called for remote siting of LNG terminals. The FPC/FERC also was deemed likely to deny the Port of Los Angeles site on grounds of the recently discovered earthquake fault, though this site was favored by the local authorities. Again on the local level, the authorities of Oxnard seemed increasingly unlikely to approve a terminal, and Western faced a complex and lengthy approval process with Santa Barbara County which held approval authority over the Point Conception site. On the state level, it seemed unlikely that the CCC, placing priority on public safety, could be convinced that an LNG terminal was safe enough for the Oxnard and Los Angeles populated areas. But the CCC also faced problems in approving the remote Point Conception site, where the marine life, kelp beds, surfing breaks and spectacular views represented the types of resources the CCC was created to protect. To complicate an already complex situation, this site was being actively opposed by the Bixby & Hollister ranch associations, who owned the land, and by the Sierra Club, which opposed LNG on two fronts: they argued that California did not need the gas, but if it were imported the facility should be on a remote site. In summary, Western faced the possibility of not obtaining all the needed approvals for any of the three sites.

THE LNG TERMINAL SITING ACT OF 1977

In view of this impending stalemate the utility companies turned to the state legislature for help. Their goal was to remove permitting authority from the many local interests and the FPC and to place it in the hands of the more congenial California Public Utilities Commission (CPUC). The CPUC was the principal state body involved in power plant issues, primarily in the rate-setting process.

The initial legislation (Bill AB220), introduced by Assemblyman Goggin in response to the growing concern over LNG safety, was, however, not acceptable to the utility companies. Though it would have given the CPUC exclusive authority to certify a proposed LNG facility, it required that the CPUC consider the feasibility of both remote on-shore and off-shore sites. In addition, it required that the CCC and the California Energy Commission (CEC)[6] offer second opinions on the feasibility decision. The Energy Commission was known to oppose the CPUC on the question of LNG for California; in its 1977 policy report to the Legislature, the Commission raised questions about LNG safety, needs, and costs. In the opinion of Western, this bill would have effectively prevented the siting of LNG facilities in California (Western 1978). So Western's parent company went to battle for a rival bill (S.B.1081) which vested the CPUC with one-stop licensing authority, precluding any real interference from the Energy Commission.[7]

The resulting legislation was a compromise between the environmentalists, who supported consideration of off-shore sites, and those who saw an urgent need for an LNG facility to assure energy and jobs. The CPUC was chosen over the more conservation-minded California Energy Commission as the agency with state permit authority, preempting local

[6]The California Energy Resources Conservation and Development Commission (the Energy Commission) was created in 1974, by, as the title suggests, both the environmentalists and the utility interests. The Commission was charged with the promotion of conservation and alternative technologies and was given the authority to issue power plant siting certificates--a way of streamlining the siting procedures. (For a brief case history of the Commission see McDonald 1979).

[7]The CEC reports to the legislature in a bienniel report on California's future energy needs and supplies. It has developed a sophisticated forecasting model which generated demand projections below those of the CPUC and of industry. The role of the CEC in the LNG siting process is one of technical consultant to the CPUC.

governments. As a bow to the conservationists, the CCC was given the mandate to choose and to rank possible sites, and to pass these rankings on to the CPUC. It was agreed that the site would not be off-shore, as some environmentalists wished, nor could it be in a populated area, as the gas utilities wished. Indeed, a nonpopulated area was strictly defined. There could be no more than an average of 10 people per square mile within one mile of the terminal, and no more than 60 people per square mile within four miles of the terminal.

THE PRESENT STATUS OF CALIFORNIA'S LNG TERMINAL

In accordance with the Siting Act of 1977, the CCC evaluated 82 sites, 18 of which were nominated by the public. The CCC was required by law to rank the sites proposed by the applicants. Of these 82 sites, only four,[8] including the Point Conception site, met the population standards, and were not infeasible because of adverse wind and wave conditions, earthquake faults, soil conditions, or other factors. The CCC passed these rankings on to the CPUC, which eliminated all but the third-ranked Point Conception site, finding that transients (campers, etc.) near the sites, on roads and at public parks, made the other sites unsafe.

This, however, was not the end of the story. During the course of the screening process, earthquake faults were discovered at Point Conception. For this reason, the CPUC could only conditionally approve the site, stating in its July 1978 decision (the deadline date set by the 1977 Siting

[8] These sites, in order of their ranking are: the US Marine Corps base at Camp Pendelton, Rattle Snake Canyon, Point Conception, and Deer Canyon.

Act) that this approval was conditional on Western showing that the faults presented an acceptable risk to the terminal.

At the same time as the state proceedings, Western had filed with the federal government for a license to import gas to Point Conception. With the reorganization of the Department of Energy, the PacIndonesian file was transferred from the ERA to the FERC, which undertook an extensive environmental assessment. Though the staff of the FERC preferred the Oxnard site, the Commission decided in favor of Point Conception to avoid a further confrontation with California law. This approval was conditional upon the results of the fault investigations.

These investigations have revealed additional faults at Point Conception. Spurred by this new information, as well as by a growing sense that California may not need, or want Indonesian natural gas, opponents have appealed the decision at the federal level. At this time, the Washington, DC Court of Appeals has remanded the case to the FERC, requesting an unconditional "go" or "no-go". Another round of hearings, briefs, and counter-briefs will follow. We await the decision.

THE ROLE OF RISK ASSESSMENTS IN THE PROCESS

During the course of events in the California LNG terminal siting debate, there were seven major risk assessments carried out for the three prospective sites: Los Angeles, Oxnard and Point Conception. To understand the role these assessments played in the process, as well as in the outcome of the debate, it is instructive to review their content and use. For the sake of brevity, and with no loss in generality, I will limit my discussion to the early studies concerning the Oxnard site. These studies, the Science Applications, Inc., risk assessment (SAI 1975), the Federal Power Commission risk assessment (FPC 1976), and the Socio-Economic Systems risk assessment (SES 1976) will be discussed in turn.

Science Applications, Inc., Risk Assessment

As part of its case for the Federal Power Commission, the applicant commissioned a consulting firm, Science Applications, Inc. (SAI), to carry out a risk assessment of the proposed Oxnard terminal. This study was elaborate, involving calculations of probabilities of vessel accidents, tank ruptures, LNG spill sizes, methane cloud dispersion and ignition, and the resulting fatalities. The computer model developed for cloud dispersion was deemed one of the two best in a Coast Guard review of several models (Havens 1977). Ship collision calculations also involved a computer model, calibrated to statistics from several harbors.

The SAI results were presented in the form of several different indices of risk. Individual annual probabilities of fatality due to the terminal were presented in the format of iso-probability contour maps of the site (see Figure 1). These probabilities ranged from a maximum of $1.5 \cdot 10^{-7}$ near the terminal to less than 10^{-10} beyond three miles for the most conservative (risk-overstating) set of assumptions. Other contour maps were presented for less conservative assumption sets. The maximum individual probability of a fatality resulting from the LNG terminal was compared to other risks. For example, the individual probability of dying in a fire was reported as 220 times greater than the LNG risk; chances of a plane falling on a person in the site vicinity was reported as

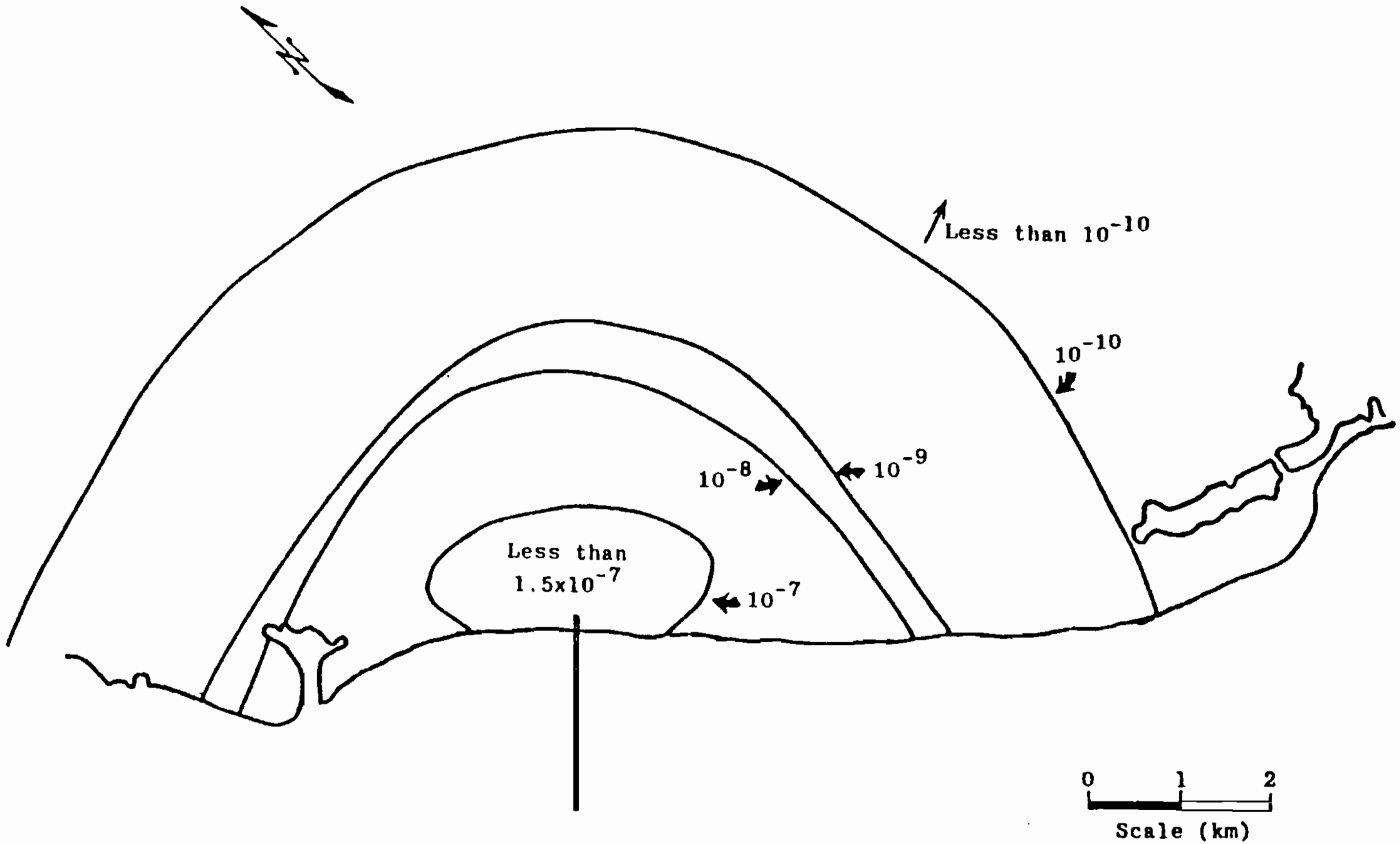


Figure 1. Iso-probability contour map for Oxnard, most conservative assumptions.
Source: SAI (1975)

10 times greater than the LNG risk. Annual probabilities of catastrophes were also presented, including 10^{-8} for a 2,000 to 10,000 fatality year, and $1.4 \cdot 10^{-57}$, or "one chance in 710 septendecillion," for the maximum catastrophe of 113,000 fatalities.[9] The study concluded that LNG risks at the Oxnard site were "extremely low." The FPC decision of July 1977 cited all the various numbers mentioned above, noted the conservative assumptions, pointed out that no party disputed the findings, and found that the Oxnard site involved levels of risk sufficiently low for FPC approval.

Federal Power Commission Staff Risk Assessment

The staff of the FPC also carried out a risk assessment as part of the Environmental Impact Statement (EIS) to be presented to the Commission at the July 1977 hearing. This assessment made use of less elaborate models and fewer resources than the SAI study in reaching its conclusions. The logic of the report can be stated quite simply: All significant risks were seen as arising from ship accidents. While this assumption is plausible on technical grounds, the assessment did not defend the assumption with analysis. All accidents were assumed thus to occur at least as far from shore as the end of the 6000 ft (1.8km) trestle of the Oxnard facility. Since the FPC staff determined that the maximum travel of the flammable vapor cloud and maximum distance of significant fire radiation effects were both less than 6000 feet, the risk was deemed to be "negligible." The report concluded that ship transport to the Oxnard site

[9] For comparative purposes, another study was cited that gave the probability of a 32,000 fatality plane crash (into a race track) as 10^{-10}, five times greater than the probability of 2,000 to 10,000 LNG fatalities for a different set of assumptions than that used to get the 10^{-8} number above.

"constitutes(s) an acceptable risk to the public."

As with the SAI study, the results of the FPC staff assessment seem to have been accepted at the FPC hearing. The decision of July 1977, cites both the FPC and SAI results in support of its approval of the Oxnard site.

Socio-Economic Systems Risk Assessment

As part of the required Environmental Impact Report, the city of Oxnard commissioned a consulting firm, Socio-Economic Systems, Inc. (SES), to carry out a risk assessment of the LNG terminal. The SES study took a broader look at the problem than the previous two assessments. Rather than characterize the risk solely in probabilistic terms, the report presented 26 "population risk scenarios," where maps of the Oxnard area showed shaded maximum plume areas or fire radiation zones for each of several wind directions, spill sizes, etc. (See Figure 2). Each scenario characterized a "population risk," or the number of people covered by the maximum plume or fire zone, which ranged from 0 to 70,000. These scenarios could be described (though SES did not) as maximum credible accidents. Though the scenarios were not accompanied by any estimates of their probabilities, they would have been quite low.

In the section immediately following the scenarios, the SES report presented a probabilistic analysis, which combined numbers and assumptions from the SAI and FPC studies as well as a Coast Guard study. This section chose to use the most conservative assumptions and numbers of each of these studies, pointing out the wide differences in the numbers. For example, the FPC used a probability of ship collision more than 5600

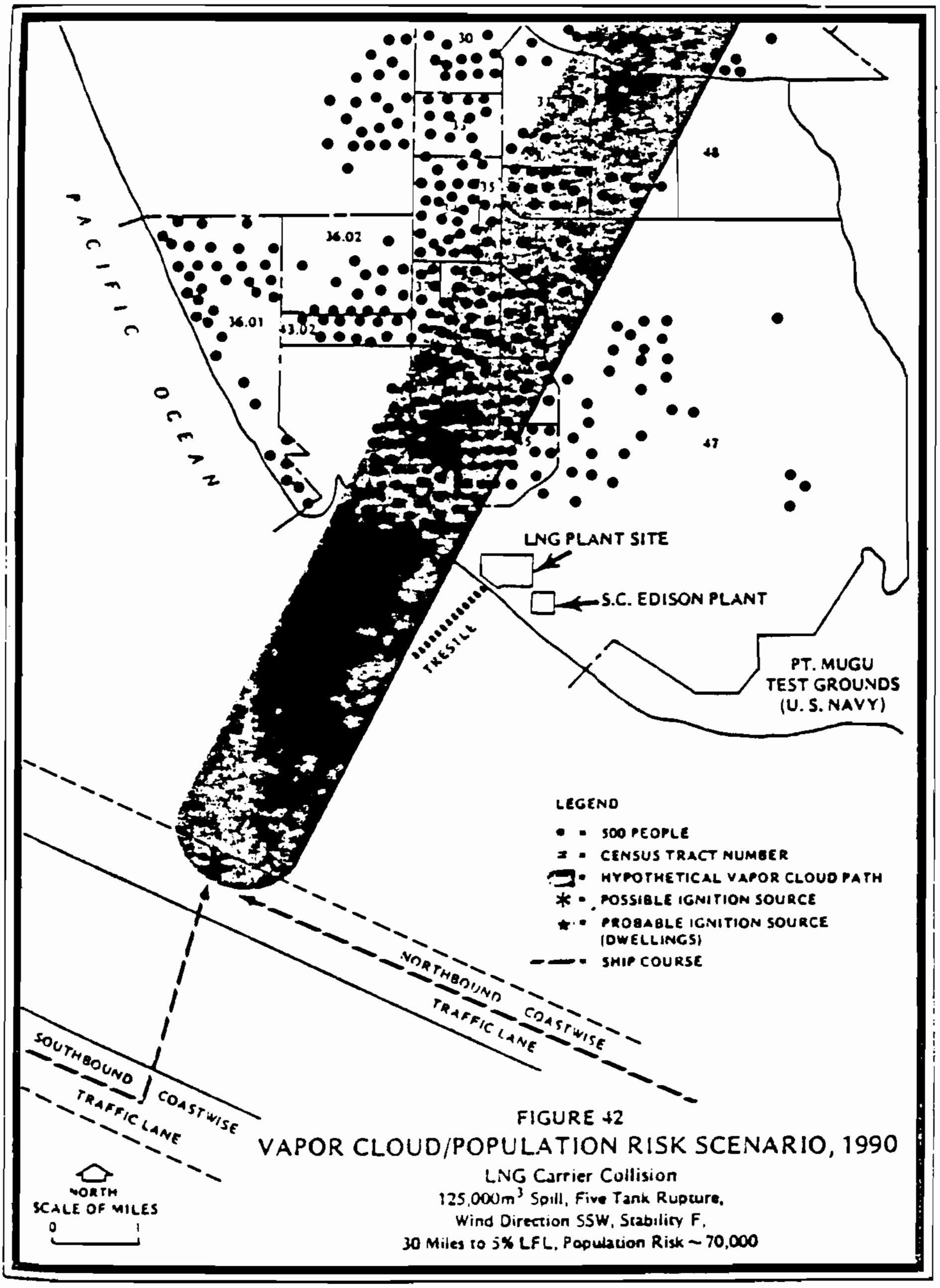


Figure 2. SES population risk scenario for Oxnard.
Source: SES (1976).

times larger than the one used by SAI. These numbers (SES and SAI estimates) were compared with expected fatalities from other hazards. While SAI estimated the LNG risk to be 7 times higher (in terms of expected fatalities) than a hypothetical Oxnard nuclear power plant, SES estimated the LNG risk to be 2900 times higher.

The SES report also plotted annual probabilities of catastrophes against the numbers of fatalities involved, for the SAI and SES estimates, and other hazards for comparison (see Figure 3). Once again, the SAI estimates for LNG were higher than the numbers for a nuclear plant, while the SES estimates were higher still. In marked contrast to the other two assessments, the SES study concluded that in view of the problems of estimating risks with very little experience base, and the differences in risk estimates between reports, "it is not now possible to state confidently that the proposed facility poses a 'low probability' of a high consequence accident."

As it happened, the SES report was never used in an official decision process, because the California LNG siting process was changed by new legislation in 1977, which ruled out non-remote sites such as Oxnard. However, the SES report may have been influential in unofficial ways. The population risk scenarios, which allowed local residents to see some deadly methane plume covering their own homes, in Ahern's (1980) words "electrified opposition to the terminal." In addition, the generally cautious tone of the report may have increased the sense of caution and may have dampened support for the terminal by the City Council. The report seems to have generally increased opposition to the terminal, opposition which led eventually to the remote siting provision of the 1977 siting

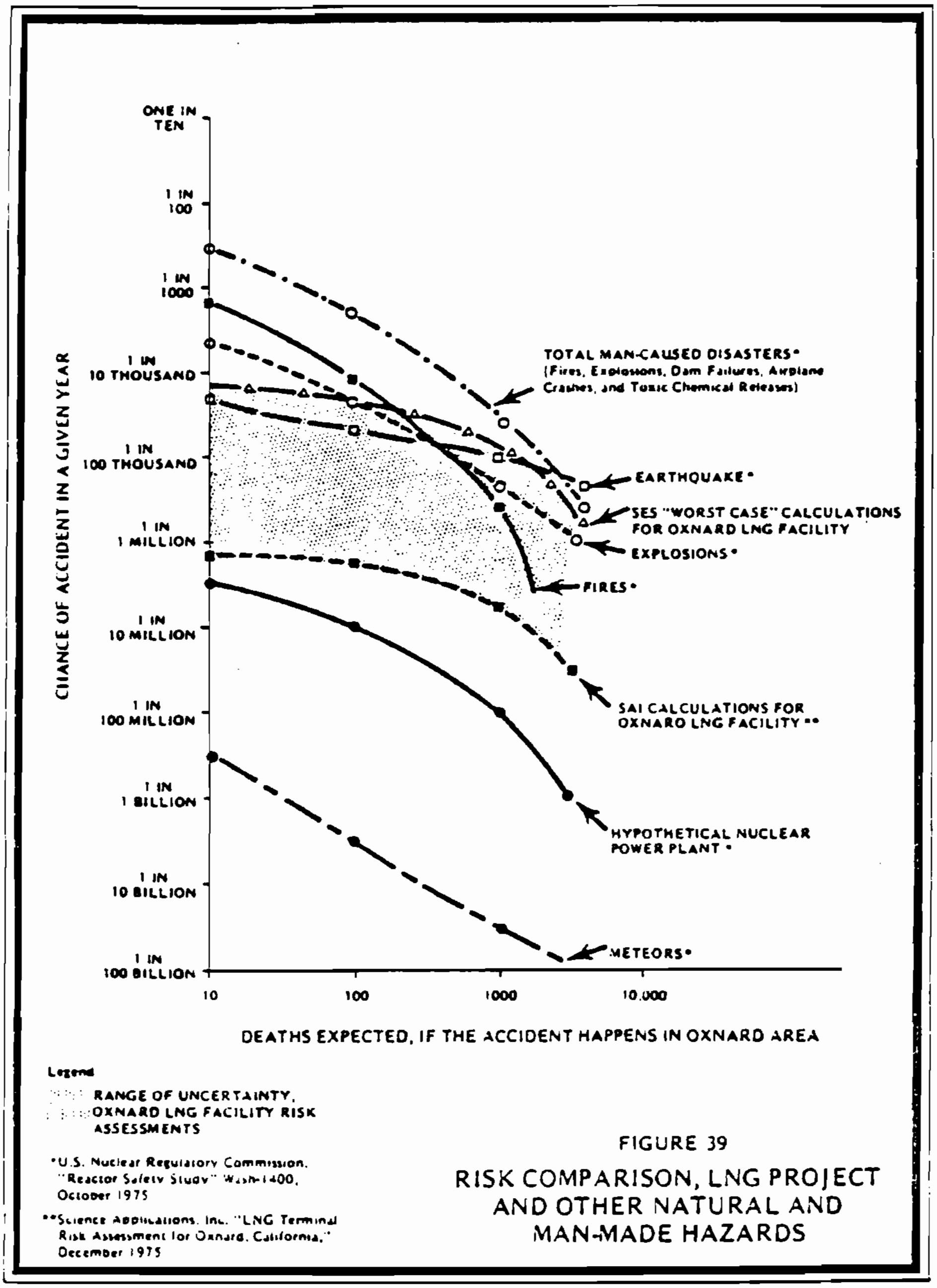


Figure 3. Probabilities vs size of catastrophes.
Source: SES (1976)

legislation. As late as 1980 one of the authors was told by a state legislative aide that the state could not site a plant that could kill 40,000 people. The 40,000 fatalities matches the format of the SES report.

SOME ISSUES RAISED BY THE CALIFORNIA SITING PROCESS

In the following, the more obvious issues that have become apparent from our study of California's siting process are listed. This list is not in any sense complete and should be considered in the broader context of the "Issues Paper" by the IIASA/MMT Risk Group. It is hoped that the following discussion will serve as a starting point for discussions with the Task Force Meeting participants.

1. In the discussion of siting issues, it is important to begin by making the distinction between the question of *whether* to site the facility and that of *where* to site the facility. Whether to have a facility ultimately depends upon national (regional) interests or objectives. In the energy debate, the lines are often drawn between two different objectives or futures one of large-scale technology, high economic growth rates, and a centralized level of decision making; or one of small-scale technology using, where possible, renewable resources or recycling, steady-state economy, and decentralized decision making. The resolution of this conflict will depend on the political system, where national goals are arrived at through an interaction of various interests. In the case of the California LNG controversy, these interests or "stakeholders" include the industry or utilities, the federal, state and local governments, the organized action groups,

the unorganized consumers, those who benefit from an unspoiled coastline and those who benefit, as well as those who do not, from *generalized* economic growth. The question of how legitimate the stakeholders view the political decision process is a basic issue which is germane to most of what follows here.

The question whether to employ a technology is often lost in the debate over where to site the facility. This seems to have been the case in California where, at least at the state level, the question of need was first debated quite late in the process. On the federal level, it is interesting that the utilities' projections of gas needs were adopted by the Federal Power Commission. The only dissenting voice was from the California Energy Commission, a rival of the CPUC, which published a low-energy scenario for California. Though the Energy Commission might have been a logical choice to make the final siting decision (its mandate to site electricity generating plants could have been extended to LNG facilities), the Legislature in the 1977 Siting Act chose instead to give siting authority to the CPUC whose primary role had been a financial regulatory agency. In the Siting Act, the Legislature explicitly decided the question of whether to have a LNG facility and tried to ensure prompt resolution of the siting problem by its choice of the CPUC. However, this decision was made nearly five years after such a facility had been proposed by the utilities.

2. This brings up the question of the *direction* of the decision process. In the US energy sector most projects are initiated by the industry, as opposed, for example, to the transportation sector where projects

(roads, etc.) are planned by the government and carried out by private industry after competitive bidding. A desirable mix of public and private enterprise involves tradeoffs between the advantages of private initiative and those of national planning.

3. More specific to the above issue is that of one-stop licensing. Before 1977, the direction of the California process was clearly bottom-to-top since it was necessary for the industry to obtain permits from scores of local authorities. However, this picture was changed by the 1977 Siting Act which gave one agency, in this case the CPUC, the mandate to grant a siting permit (it was also necessary to have federal approval, but the DOE appeared willing to accept the decision of the state). There are obvious pros and cons in this shortened procedure, depending to a large extent on national objectives. Because an LNG facility can benefit the greater population, but can impost costs (risks) on a small local population, a procedure requiring local approval inevitably proves difficult. Yet, if the decision process itself is important, taking the decision out of local control is clearly undesirable. Here one might investigate other mechanisms to include in a fair way the local population, for instance, through 'bidding schemes' which would allow for compensation to those who perceive themselves to be at risk.

4. An issue related to the question of local sovereignty is that of the appropriate incentive system for choosing an acceptably safe site. If the local government has veto power, it is possible that industry would be compelled to locate where it receives the least resistance, i.e., in remote areas, or to compensate local communities for the

risks. Another related, and important question is who is liable for an LNG accident?

5. A difficult question is how the decision process itself can be evaluated, what are the relevant indicators? Included here might be the following:

   - Is there a forum for public debate?
   - What are the delays?
   - Are all the alternatives considered?
   - Does it encourage the best possible outcome in view of the opposing interests?
   - How legitimate do the stakeholders view the process?

The move to one-stop licensing seems to represent a tradeoff between the first two of the above. The purpose of the 1977 Siting Act was to ensure the siting of an LNG terminal without extensive delay--at some sacrifice in local participation. This Act, in the interest of maximizing public safety and minimizing further delay, might have precluded finding an optimal site by imposing the population and the on-shore siting constraints. By "optimal" we can begin by asking whether, in the absence of these constraints, a site could have been identified that would have been viewed as more desirable by *all* the parties. A more difficult definition of "optimal" would involve making equity judgments, or finding a site that would have been preferred by some people at the expense of others. It seems that the Oxnard site was favored by nearly all the stakeholders including the utilities, the Sierra Club,[10] the CPUC, the CEC, and the

[10]The Sierra Club changed its stand in early 1977 to oppose the Oxnard site.

FERC. A puzzling question is how a site that had support from so many opposing groups could have been ruled out by the political representatives.

Finally, we might want to consider if this process, either pre- or post-the 1977 legislation, encourages an imaginative consideration of all the possible alternatives. For instance, is it necessary to have one large facility, or could one imagine a series of storage facilities presenting risks on the same order as peak-shaving plants located in industrial areas? Or, were the possibilities for off-shore siting given sufficient consideration. Where a project is defined by industry before it is considered by government planners, there exists the danger of tying the decisions to minor variations of the proposed concept.

6. Turning to the role "risk" played in this process presents a number of exciting issues. There are, of course, technical problems of estimating the possible consequences and their probabilities, determining the error bands for existing estimates and designing tests, experiments and models for improving these estimates. An equally important problem concerns the public perception of the risk: what factors or dimensions of the hazard explain the observed reactions, can public response be in any sense predicted? What role do the media, the information campaigns, and published risk assessments play? Here analogies to the nuclear power debate become apparent--large-scale technology, low-probability, high-consequence

events, involuntary, passive exposure, etc.

Of particular interest is the catastrophic, or potential holocaust dimension of the risk which seems from a number of published sources to have played a major role in public perception of nuclear power. In the case of LNG, this aspect of the risk might be viewed as having been the decisive element in the California LNG siting debate. One possible hypothesis is that the siting procedure would have proceeded routinely, that is, after completion of all the necessary reports and hearings, the facility would have been located at Oxnard as recommended by the FPC, had it not been for one crucial event: the publication of a worst-case scenario showing that 70,000 residents of Oxnard could be victims of an ignited LNG vapor cloud. After publication of this report not only the public, but all the relevant government agencies with the exception of the FPC/FERC, became increasingly risk averse. This report seems to have had considerably more effect on sensitizing the public to the risks of LNG than an earlier event--the explosion of an oil tanker in the Los Angeles harbor. The latter showed that an accident was possible whereas the former showed that a holocaust was possible! The differences in public reaction might be explained by the existence of a comparatively well-organized opposition in Oxnard drawing especially from the 10,000 residents who were within a two-mile radius at the proposed facility. Yet, the publication of a catastrophe scenario certainly had a profound effect. (This is especially interesting since it seems that there was a similar turning point in the siting of an LNG facility in the Netherlands.)

Regarding the risk studies, and the various reactions raised by the particular formats chosen for presentation of the results, we can observe that there are what has been described as 'valium' and 'doomsday' reports. Recognizing that these reports were written *to persuade* opposing parties, usually in the context of a hearing, it is useful to ask what their proper role is. For this purpose, we might ask the following questions:

- What assessments should be made?
- What methods should be used?
- How should the results be presented?
- Who should make the assessments?
- Who should sponsor them?
- Who will assess the assessors?

And on a broader level, we might ask:

- Is there a notion of an *acceptable* level of risk?
- Do risk studies make a difference?

7. Another important issue concerns the decision process. One estimate by the utility puts the cost of delay at about $1 million per day. To this figure one would have to add the costs of the myriad of reports, hearings, consultants, etc. How would the final figure compare with the extra cost of remote siting of an off-shore facility, of a more (or less) expensive alternative to LNG? Would it be possible, for example, to move the residents from the two-mile radius (or a 5-mile radius) of the Oxnard site at a cost less than that of the cumbersome decision process?

8. Another point that might be investigated is the absence of any sort of referendum on the LNG question in California for Los Angeles, Oxnard, or Point Conception. Could the results of such a referendum be *ex post* predicted?

9. In this regard, a decision-analytic framework might be an appropriate starting point. The most important role for a systematic approach to decision making is to help specify a likely scenario with respect to a particular problem based on discussions with the key stakeholders. In so doing, it is particularly important to specify the set of decisions that have to be made and the role each stakeholder is likely to play with respect to each of the many decisions.

REFERENCES

Ahern, William R. 1978. *Energy Facilities and the California Coastal Act*. San Francisco: California Coastal Commission.

Ahern, W.R. 1980. "California Meets the LNG Terminal," *Coastal Zone Management Journal*, 7:185-221.

California Public Utilities Commission. 1978. Final Environmental Impact Report for the Point Conception LNG Terminal Project, Vol. 1, Summary of Revisions to Draft EIR California.

Federal Power Commission (FPC). 1976a. Final EIS on WLTC's Proposed Point Conception, California, LNG Terminal, April.

FPC. 1976b. Pacific-Indonesia Project, Final Environmental Impact Statement. Bureau of Natural Gas, Federal Power Commission Staff. Federal Energy Regulatory Commission, Washington, D.C., December.

FPC. 1977. Initial Decision on Importation of Liquefied Natural Gas from Indonesia. Federal Power Commission. Federal Energy Regulatory

Commission, Washington, DC, July.

Havens, J. 1977. "Predictability of LNG Vapor Dispersion from Catastrophic Spills onto Water: An Assessment," US Coast Guard, Washington, DC.

Kunreuther, H., J.W. Lathrop, and J. Linnerooth. 1981. "A Descriptive Model of Choice for Siting Facilities: The Case of the California LNG Terminal," IIASA Working Paper, WP-81-106, Laxenburg, Austria: IIASA.

Mandl, C., and J.W. Lathrop. 1981. "Assessment and Comparison of Liquefied Energy Gas Terminal Risk," IIASA Working Paper, WP-81-98, Laxenburg, Austria: IIASA.

McDonald, Alan. 1979. *A Short Case History of the California Energy Commission.*

Science Applications, Inc. (SAI). 1975a. "LNG Terminal Risk Assessment Study for Los Angeles, California," Prepared for Western LNG Terminal Company, SAI-75-614-LJ. La Jolla, California (Chapters 1, 8, & 9 only).

SAI. 1975b. "LNG Terminal Risk Assessment Study for Oxnard, California," Prepared for Western LNG Terminal Company, SAI-75-615-LJ. La Jolla, California.

SAI. 1976. "LNG Terminal Risk Assessment Study for Point Conception, California," Prepared for Western LNG Terminal Company, SAI-75-616-LJ. La Jolla, California.

Socio-Economic Systems. (undated). on *Draft Environmental Impact Report for the Proposed Oxnard LNG facilities*. Los Angeles, California.

US Department of Transportation (US DOT). 1980a. *Liquefied Natural Gas and Liquefied Petroleum Gas: View and Practices*. COMDTINST M 166164. Washington, DC: Coast Guard.

US DOT. 1980b. Liquefied Natural Gas Facilities, Federal Safety Standards; Final Rule and Proposed Regulating. Federal Register, February 11.

Western LNG Project. 1978. "Final Environmental Impact Statement," FERC/EIS-0002F. Washington, DC: Federal Energy Regulatory Commission, Vol. I, No. CP75-1040; Vol. II., No. CP75-83-2; and Vol. III, No. CP75-140.

APPENDIX: Indonesia LNG Project; Summary of Major Events (1972-1975)

	1972	1973	1974	1975
January			Indonesian government refuses to approve PacIndonesia contract	PacIndonesia and Pertamina agree to LNG pricing formula changes California Energy Commission created
February			PacIndonesia supplemental application filed with FPC	
March				Revised LNG contract approved by Indonesian government Amendments filed with FPC on LNG contract changes and Oxnard terminal site
April				FPC consolidates Western LNG and PacIndonesia applications
May				California Coastal Plan: CCC favors remote siting
June	SUMMER: Discovery of Natural Gas in Arun field publicly announced			
July				
August				
September	Letter of intent signed by PacIndonesia and Pertamina for purchase of LNG	Contract signed by PacIndonesia and Pertamina to purchase LNG	Western LNG filed application with FPC for terminal facilities at Los Angeles, Oxnard and Point Conception	
October			Submits Risk Assessment study	
November		PacIndonesia application to import LNG filed with FPC		
December		Japan signs LNG contract with Pertamina		FPC hearings being on Indonesian project

Indonesia LNG Project: Summary of Major Events (1976-1979)

	1976	1977	1978	1979
January	Pacindonesia signs Memorandum of understanding with Pacific Gas and Electric Company on project	Initial State LNG legislation introduced in California assembly (offshore siting possible)	Petitions for rehearing of ERA decision filed	SOLNG filed for consolidation of hearings FERC evidentuary hearings completed, briefing schedule established
February		FPC Hearings conclude on Pacindonesia project	ERA grants rehearing on certain issues	FERC suspends briefing schedule in siting case
March		California assembly subcommittee on energy begins hearings on LNG decision	Negotiations begin with Pertamina on a revised pricing provision	Temporary injunction issued limiting Native American site access for strictly religious purposes
April		Pertamina agrees to extend LNG contract for third time, to October 6, 1977 Oxnard Planning Commission certifies the State EIR is adequate, but approval appears unlikely	Draft Federal EIS on Little Cojo Bay site issued CCC ranks sites (Pendleton first)	FERC unanimously denies SOLNG consolidation motion and reinstates briefing schedule ERA issues opinion Number Six on treatment on costs
May	Draft Federal Environmental Impact Statement issued		ERA and FERC resolve jurisdictional issues	
June		Los Angeles City Council approves harbor for LNG	Indians announce religious significance of site	FERC rejects request for additional gas supply studies California Supreme Court denies request for review
July	California Assembly subcommittee on energy begins hearings on State's role in siting LNG receiving terminals	FPC Administrative Law Judge recommends approval of Indonesian project and Oxnard as Site Western faces stalemate	Renegotiated LNG pricing provision submitted to ERA CPUC conditionally approves terminal site	CPUC reaffirms July 31, 1978 decision on terminal site
August	California Coastal Act suggests remote siting Draft EIR for Oxnard	Japan receives first shipments of Indonesian LNG from Badak facility	Petitions for rehearing CPUC decision filed	FERC Administrative Law Judge approves terminal site
September		Governor Brown signs the California LNG Terminal Siting Act of 1977	Japan receives first shipments of Indonesian LNG from Arun facility Applicants' motion for expediting procedures filed with ERA and FERC requesting decision on site location by December 31, 1978	ERA grants final approval to import LNG DOE delegates terminal siting authority to FERC FERC conditionally approves terminal site
October		Department of Energy (DOE) created "Kick-Out" date on LNG contract with Pertamina passes. Pertamina free to cancel Western LNG files application with CPUC for initial LNG receiving terminal at Cojo Bay near Point Conception	ERA issues opinion Number Two approving revised contract pricing provision FERC staff releases FEIS	CPUC solves air quality mitigation conditions, construction period transportation plan, seawater intake system, and powerline route
November		ERA of DOE begins oral hearings on Indonesian LNG project CPUC begins hearings on application for terminal Western LNG files amendment with ERA to construct LNG receiving terminal at Cojo Bay site	CPUC denies petitions for rehearing Opponents file with California Supreme Court seeking reversal of CPUC siting decision SOLNG files application with FERC for Deer Canyon receiving terminal	
December	Oil tanker Sansinena explodes in Los Angeles harbor Final Federal EIS issued	ERA issues opinion Number One conditionally approving LNG from Indonesia, pricing provision disapproved	Hearings begin at FERC on FEIS	

DISCUSSION COMMENTS

CIERAAD: I have three points on which I would like to comment. One of Joanne's questions was "Is there an acceptable level of risk?" I think that perhaps there is not, or at least I do not think it is possible to say "Here is the Line." My second point relates to Joanne's question: "Did risk studies make a difference?" I do not think there is an easy answer to this query. For instance, frequently safety is an important topic for discussion but it is difficult to know to what extent studies on the risk of LEG were taken into account by the different parties. My last point is a clarification of a comment you made regarding TNO. One of the main issues within the TNO Risk Assessment Group is whether there should be a norm of acceptability. I was, therefore, stunned when you mentioned limits that TNO has come up with when I do not think they did. You may have confused the government's position, or the position of the province of Groningen.

LINNEROOTH: I agree with your comments on acceptability. But I think Mr. Mehta, from indications in his paper, might give you an argument. I think you are right on my question "Have risk assessments made a difference?" It was certainly very vague and perhaps I should have asked "What difference *can* they make?" I suppose I was over simplifying. Yet the major decision on switching the site in Holland *was* political". Risk analysis played a small role. But you are right, we should keep the question at a broader level.

CLARENBURG: It struck me that you, for an example, compared the probabilities of various accidents. We have found that the public has no notion about probabilities. The public reacts to a risky activity in terms of a maximum potential accident. That is what the public can understand.

RAVETZ: I would like to inject quite a different consideration. When Joanne showed us those two sorts of tables, you can call one the valium and the other the amphetamine, it occurred to me that no one sitting around the table now would play the following game anymore (at least, I hope not), of saying "Lookie, lookie! How trivial it all is. We can tell you either to go to sleep or to jump off the cliff." Although risk assessment is clearly still uneven in its development, there has been a very rapid maturity, an awareness, of what is involved in a risk assessment, both on the technical side and on the political side. I have watched it much more closely in connection with nuclear power than with the LNG question. And it struck me during your talk that I got irritated.

I thought of a useful analogy that you could see in the early development of various disciplines, that emerged from a very undisciplined political state. In the early days, either the baron had a false claim to his castle or the the local saint was actually spurious. At various points in the sixteenth and seventeenth century there developed techniques for assessing documents which at first were introduced in a political way. By the end of the seventeenth century there was fair agreement among historical scholars as to how you could assess a document. Now they still argued but at least they were arguing about the same thing. With respect to the field of risk assessment, we are almost on the brink now of having a certain agreement about what can be said and what cannot be said, by people who are having a dialogue.

OTWAY: I want to congratulate Joanne for asking the right questions, though I am not sure of the answers. I think they are important questions, and ones I have been asking myself. On acceptable risk, of course, we all know there is no such thing as "drawing the line"—its a silly notion. At one time I maintained that there was a line of *unacceptable* risk, where a regulator can say "I am sorry you cannot have that even if you want it." The first time I suggested this in a meeting, somebody said "I am glad to hear some common sense, because the risks caused by not having the benefits of my technology are larger than its risks, therefore my technology must be accepted by the regulators trying to protect people against unacceptable risk." After that response I concluded that there is also not an unacceptable level.

DALL: I think it is crucial to recall that risk analysis is done by someone for someone, in a goal-oriented context rather than at an abstract level. The specific objectives determine to a large extent the work that is done.

III. PARTY PERSPECTIVES

An important lesson from IIASA research to date is that there is no simple decision structure that describes the siting process. It has become clear that a central factor in understanding the problem of managing technological risks is recognizing the complexity of the decision structures involved.

Each interested party views the problem from a different perspective, and so brings a different structure to the problem. The industry involved may view the siting problem as a choice among alternative investments, where such factors as net return on capital and energy-supply security are primary concerns. Local interest groups may view the problem as one of trading safety for jobs or perhaps as a land-use problem. Some interest groups may consider the problem as one of protecting natural resources. Government planning agencies may be concerned with compatibility between siting plans and their long-term land use plan. Regulatory agencies may view the problem in terms of public safety, energy supply security, and the economics of the project (reasonable price for the ratepayer, etc.).

Each of the participants at the Task Force Meeting is personally involved in the LEG siting issue in his/her respective country. Each views the problem from a unique perspective shaped by the national context, the individual's affiliation, and level of involvement; thus, each brings a unique structure to the problem. The papers and discussions in this section illustrate the following different perspectives: Environmental and Citizen Groups, Industry, and Regulatory Agency.

A. ENVIRONMENTAL AND CITIZEN GROUPS

Although national and global environmental groups have reported a strong concern over the safety implications of high-technology LEG import and export facilities, they have for the most part lacked the staff time and resources to participate actively in LEG discussions. Local citizen groups, on the other hand, have mobilized either to support or to oppose LEG facilities. In some instances, fervent and vocal opposition groups have arisen to fight industrial siting plans. Without exception, these groups have not been opposed to the import/export of LEG, *per se*, but to the particular site selected for the terminal. In other cases, the local population appears to have actually supported the site. The papers and discussions presented in this section explore the LEG siting process with special consideration given to social and environmental issues.

Papers in this category include those presented by Lucas Reijnders dealing with "Societal Interest" in a general sense, and by P.D. Mehta on a local view of terminal siting in the Mossmorran/Braefoot Bay case.

B. INDUSTRY

Though the perception industry has of the LEG siting problem differs among countries, some common themes emerge. Generally, industry views the siting question as one of finding the least-cost site, feasible in terms of berthing conditions, yet acceptably safe. Industry also tends to emphasize the need for imported natural gas and its desirability as a clean burning fuel. Thus, industry often feels frustrated when its projects are delayed or blocked by other considerations imposed by governmental regulations and local opposition. As illustrated by the papers in this section, industry seems to prefer to focus its attention and expertise on the technical aspects of LEG siting.

The two papers in this section are by Yu. S. Oseredko and by Yu. I. Maksimov, and respectively deal with the construction of a natural gas terminal and the economic problems of improving production and transportation of natural gas in the USSR.

C. GOVERNMENTAL REGULATORY AGENCIES

The level of governmental decision making is a key issue in the LEG siting process. National interests may conflict with local interests, and it may have to be resolved as to whether local or national authorities will make the final decision. The degree of centralization of the LEG siting decision network varies among the countries studied. In some countries, hundreds of permits and approval are necessary to site a facility; in other countries, the decision rests in one central agency. There are obvious advantages and disadvantages to either case, and it is intriguing to ask how satisfied are the authorities with their respective systems. The following four papers provide some insights to possible answers for these questions.

The paper by Niall G. Campbell is concerned with the regulator's view of terminal siting, while Randolph W. Deutsch's paper is concerned with the regulatory framework and other factors involved in the decision making process. William R. Ahern discusses the role that technical analyses plays in terminal siting, specifically in the California case in the US. Finally, Anthony C. Barrell is concerned with the future directions of siting decisions.

SOCIETAL INTEREST

L. Reijnders
Stichting Natuur en Milieu

1. INTRODUCTION

Following World War II in Western countries peaceful applications of science and technology were held in high societal regard. In line with a tradition that was argued for the first time in a comprehensive way by F. Bacon,[1] technical progress and societal progress were considered to be intimately linked. Smoke from new factory stacks, jetliners and nuclear energy plants were hailed as milestones on the road to a better world. Self-regulation, without state-evaluation of benefits and risks, was by and large considered the best way to steer scientific and technological progress. Especially the end of the 1960s marked a change in attitude. For a substantial part of the population in rich western countries, smoke and jetnoise became pollution and nuclear energy a threat.

This change of attitude brought many high-technology activities within the scope of explicit societal decisionmaking.

LEG did not remain outside the scope of growing societal interest in decisions about high technology. This is all the more understandable because LEG highlights a disturbing paradoxical aspect of technological change, since the time that our ancestors were hunter-gathers, *id est*, that while because of "technological buffering" the impact of small environmental fluctuations on health and life time expectancy tends to decrease, catastrophability of major deviations from normal tends to increase.[2]

2. THREE APPROACHES TO SOCIETAL DECISIONMAKING ABOUT LEG

Explicit societal decisionmaking in countries with advanced state apparatuses, like industrialized Western countries, may, in principle, follow a number of different approaches:

2.1. Firstly, decisionmaking may be based on application of a coherent set of rights. In case of LEG, such a set of rights may include the right of producers, distributors, etc., to exploit one's property without undue interference by others, and the right of those potentially at risk to live without undue interference by others (with the actual meaning of undue defined by parliamentary and court decisions).

2.2. Secondly, decisionmaking may maximize aggregate utility. This approach, of which the foundations were clearly articulated by J. Bentham, has undergone sophisticated theoretical development.[3] The use of cost (risk)-benefit analyses to decide between alternative LEG related options (like LEG transport by ship, gas transport by pipeline, substitution of LEG by other fossil fuels like oil and coal or renewable energy sources) may be considered an application of this approach.

2.3. Thirdly, one may envisage a game theoretical approach.[4] Here decisions will be reached by "games" between interest groups ("parties") involved, in which each party will try to maximize group utility. In case of LEG-related decisions, parties that may take part in decisionmaking are: different branches of government, commercial interest groups pushing LEG and competing fossil fuels and feedstocks, trade unions and environmentalists.

3. IMPORTANT PROBLEMS INVOLVED IN MAXIMIZING AGGREGATE SOCIETAL UTILITY OF LEG

Protagonists of applied decision theory[5] tend to prefer approaches aimed at maximizing aggregate utility (cf. 2.2). In a similar vein, governments as a rule tend to suggest that their policies are aimed at maximizing societal utility ("welfare").

Actual practice is probably considerably at variance with an utility-maximizing approach, and would seem by and large a mixture of the approaches outlined in 2.1 and 2.3. Because, however, utility maximizing approaches are theoretically attractive, it would seem worthwhile to point out some of the difficulties that may arise on application of such approaches, difficulties that currently tend to be overlooked by cost-benefit analysts and decision theorists.

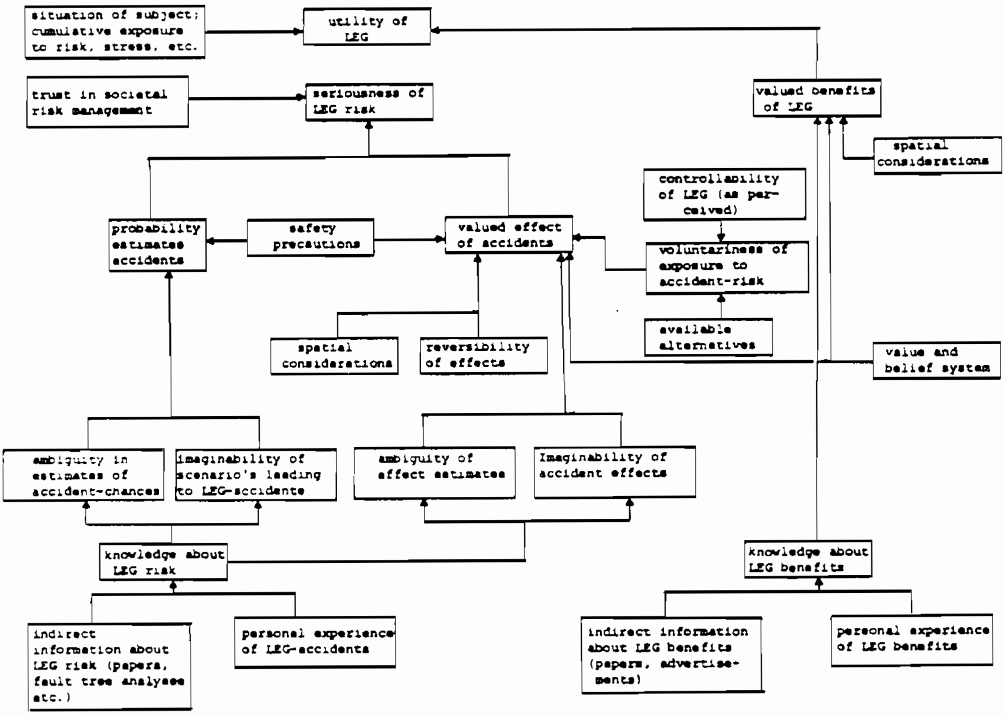
Scheme 1 gives a semi-normative semi-descriptive decision theoretical reconstruction of the genesis of utility as perceived by persons involved in LEG related decisions.

If we view this scheme against the background of societal decisionmaking it may be noted that perceived utilities of *one* activity will, as a rule, vary widely. This variation may in part be traced to obvious differences like divergences in interests. For instance, utility estimates relating to a LPG-delivery facility for motorcars will presumably be very different for drivers of LPG-motorcars, that drive by, than for a bicyclist-on-principle, that owns a house at a distance of 25m from the facility. In part, differences in perceived utility have less trivial sources.

For instance, there is considerable evidence that professional technologists (and economists) have a very different perception of probability as related to seriousness of high-technology than the public at large.[6] Whereas, professionals tend to equate seriousness with probability times effect (cf. FAFR[7]), the public at large tends to neglect probability of involuntary exposure to high technology accidents and tends to focus on possible sizes of effects. Also there is some evidence that an increasing number of branches in a fault tree may induce an increase in public perceived probability of accidents,[8] while presumably being neutral to professional risk-analysts.

The wise variation in utility as individually perceived, does--as a rule--not show up in current applications of utility maximizing approaches. Cost-benefit calculations use a single (monetary) perception, whereas available applied decision analytical procedures[9] also use one "standard" view of the matter.

A second problem that besets utility maximizing approaches in case of LEG related decisions is that of the price of life. LEG-related activities will, viewed at a societal level, take lives, and an important problem is, how to account for this in utility maximizing procedures. In cost(risk)-benefit analyses lives tend to be priced (e.g., using life-time earnings or insurance claims settled by court decisions). This way of looking at lives taken (by a third party) is incompatable with an important tradition in western thought. According to this (peacetime) tradition, life has a value but no price. Therefore, one may argue, a



Scheme 1: Reconstructed genesis of (perceived, personal) utility related to LPG-decisions.

Modified from: C.A.J. Vlek, P.J. Stallen, Persoonelijke Beoordeling van Risico's, Groningen, 1979.

third party (like a LEG company) may not exchange (the risk of taking) lives against such LEG-facilitated goods like more comfortable spaceheating or cheaper fuels for automotive power, neither has the state of freedom to legalize such an exchange (for instance, by giving out permits). According to this tradition the only justification for taking lives by a third party is that more lives can be saved than will be lost, and that all ("technically") possible precautions have been taken to reduce the expected loss of life. The choice whether or not life has a price may be expected to have far-reaching consequences for outcomes of utility maximizing efforts, and therefore merits considerable attention of those involved in risk-benefit evaluations.

A third problem that arises in utility maximizing is that of just distribution. Just distributions tend to be hot societal potatoes, and are, therefore, highly problematic aspects of societal utility maximizing. Just distributions may be considered as either boundary conditions for utility maximizing or as one of the components that contribute to aggregate utility. Those evaluating risky activities should, in principle, make a choice from the bewildering variety of distributions, that are defended as just.

They should, for instance, decide whether one should opt for the unicorn-like Pareto-optimal distribution, egalitarian distributions or the Rawls' criterion,[10] that allows for inegalitarian utility distributions in case the utility of the person relatively worst-off is still (absolutely speaking) higher than in case of an egalitarian distribution. It should also be decided whether risk benefit ratio's should be similar for all those involved or are allowed to be different.

4. THE ROLE OF TECHNICAL AND ECONOMIC ANALYSES

As may be inferred from the foregoing, technical and economic analyses are only a small part of the story of (semi-)normative approaches to societal decisionmaking.

Their importance is easily overwhelmed by other factors in the decisionmaking process. Sophisticated cost-benefit calculations are easily blown away on experiencing a low probability disaster or in controversies about the pricability of life and matters pertinent to just distribution. Elaborate Monte Carlo simulations leading to probability estimates fade away if in a democratic process citizens tend to concentrate on effects and neglect probabilities.

Though proponents of technical and economic analyses should therefore probably be satisfied with a modest estimate of their societal importance, it seems appropriate to state, that such analyses may play a significant role in elucidating for society the options open, and the consequences thereof.

A number of factors, however, seem to hinder adequate fulfillment of proper "educative roles". These factors seem to relate in part to insufficient appreciation of structural differences between the perceptions of risk-related problems by, on the one hand technical and economic experts, and on the other hand, the public at large.

Poor quality of much on-going technical and economic analytical work also contributes to educative shortcomings.

Perceptions of risks of high technology by a major part of the public and experts seem to diverge in a number of aspects. Whereas experts tend to concentrate on narrow and clearly defined issues, a major part of the public tends to focus on broader and vaguer matters. Whereas experts tend--as pointed out before--to equate risk with probability times effect, public perception often focusses on potential catastrophability. Also experts often neglect that expert-perceived controllability can easily and significantly exceed controllability as perceived by ordinary citizens, and that therefore the public focusses on potential costs. In the heat of recent acrimonious debates about high nuclear and recombinant DNA technology several experts have denounced the public point of view as "irrational". However, though perceptions of a major part of the public are different from average-expert perceptions, there seems to be no convincing argument to describe the public point of view outlined above as irrational, contrasting rational expert-outlook. A second factor that hinders proper education by economic and technical analyses is the amount of shoddy science and reasoning that pervades much on-going analytic work.

Analyses are often bent to fit preconceived conclusions of interest groups, and it is well-known "in the trade" that some risk-analysis institutes tend to consistently provide Valium-type reports, whereas Doomsday reports may be obtained by commissioning the same study elsewhere. Uncertainty is as a rule grossly underemphasized in the presentation of conclusions of technical and economic analyses, and a fog of technical details tends to obscure dubious assumptions. So far this disturbing situation has not attracted much public attention, but if the poor state of risk and cost-benefit work becomes generalized knowledge, the independent value of technical and economic analyses may erode to vanishing importance.

5. THE ROLE OF PUBLIC INTEREST GROUPS

The role that should be played by public interest groups depends on the normative approach to societal decisionmaking selected from the possibilities outlined under section 2.

Within the framework of a game theoretical approach (cf. 2.3) public interest groups should play a well defined and active role and should directly participate in decisionmaking. Within the frameworks outlined in subsections 2.1 and 2.2, their role should be more indirect and diffuse. The style of democracy favored is also important in determining a proper place for public interest groups. Clearly countries that favor fair and open debates about the pros and cons of governmental decisions will be more favorably disposed towards an important public role for public interest groups than countries governed in a paternalistic way. In non-paternalistic enlightened societies one might expect that public interest groups will get a fair chance to articulate their position *vis a vis* the massive argumentation, that governments and industry are able to buy. At the current level of sophistication, this would require guarantees for a certain amount of scientific and technical support for public interest groups.

As yet such support is scant. This in turn contributes to pressure on public interest groups to focus on a limited number of top priorities, like nuclear energy.

Scientific and technical support for public interest groups may be organized in a variety of ways. Here I like to point out two promising possibilities of support that deal with on-going or intended developments in applied technology.

Firstly, one may establish a conditional right to ask for *counter-expertise*. According to this "right" in starting major new developments, interested parties should put aside means to have the proposal evaluated by experts chosen by relevant public interests groups, who then should especially concentrate on those issues that are important for the groups involved. Secondly, one might establish "science shops", affiliated with universities or research institutes where grassroots public interest groups can obtain expert advice at low or *nihil* cost. Such science shops operate with moderate success in the Netherlands.

It may be noted, that these forms of support evade the long-term problem of developing alternative "public" technologies that may counterbalance industrial and government sponsored developments.

The most efficient way to stimulate the development of potential "public" technologies would seem to provide considerable support for non-conventional technology oriented research in (technical) universities.

REFERENCE NOTES

1. Hill, C. 1972. *Intellectual Origins of the English Revolution.* London: Panther Books.

2. cf.
   Sahlins, M. 1972. *Stone Age Economics.* Chicago: Aldine-Atherton.

   Burton, I., R.W. Kates, G.F. White. 1978. *The Environment as Hazard.* Oxford: Oxford University Press.

3. cf.
   Smith, N.M., Jr. 1956. "A Calculus for Ethics," *Behavioral Science,* 1, III-180.

   Fishburn, P. 1964. *Decision and Value Theory.* New York: Wiley.

   Fishburn, P. 1970. *Utility Theory for Decision Making.* New York: Wiley.

   Keeney, R.L., H. Raiffa. 1976. *Decision Theory with Multiple Conflicting Objectives.* New York: Wiley

4. cf.
   Rapoport, A. 1973. *N-Person Game Theory, Concepts and Applications.* Ann Arbor: University of Michigan Press.

   Olson, M. 1965. *The Logic of Collection Action.* Cambridge, Mass: Harvard University Press.

   Buchanan, J.M., G. Tullock. undated. *The Calculus of Consent.* Ann Arbor: University of Michigan Press.

5. cf.
   Keeney, R.L. 1975 "Energy Policy and Value Trade-Off," IIASA Research Memorandum, Laxenburg, Austria, December.

   de Neufville, R., R.L. Keeney. 1972. *Use of Decision Analysis in Air Port Development for Mexico City,* in *Analysis of Public Systems* Cambridge, Mass: M.I.T. Press.

   Baecker, C.B., J.G. Groof, K. McKusker. 1977. IIASA Research Report, Laxenburg, Austria, September.

6. Vlek, C.A.J., P.J.M. Stallen. 1979. *Persoonlijke beoordeling van risico's.* Groningen: Instituut voor Experimentele Psychologie, R.U. Groningen.

7. cf.
   Kletz, T.A. 1976. "The Application of Hazard Analysis to Risk to the Public at Large," Paper for the World Congress of Chemical Engineering, Amsterdam.

Gibson, S.B. 1976. *Chem. Eng. Progress*, 59, February.

la Fors, F.P.G.M., R.A.J. Badoux, P.R. Defize. 1979. "Een statistische beschrijving van risico's, waaraan de Nederlander blootstaat." Instituut INO voor Wiskunde, Informatieverwerking en statistiek, April.

8. Fischhoff, B., P. Slovic, S. Lichtenstein. 1978. *Journal of Experimental Psychology, Human Perception and Performance*, 4:342-355.

9. Refer to Reference Notes 5.

10. Rawls, J. 1973. *A Theory of Justice*. Oxford: Oxford University Press.

DISCUSSION COMMENTS

DALL: I will focus on the major points in Dr. Reijnders' paper and then draw a few tentative conclusions. I think it is clear that there are immense difficulties in generalizing across nations, as well as in extrapolating elite attitudes and behavior to public attitudes and behavior.

For instance, Dr. Reijnders notes that technical progress and societal progress, which once were seen as being intimately linked, have in the past twenty years become perceived as being discontinuous and the source of significant problems for the environment. I do not know about Europe, but in North America there has been a countervailing tradition to unrestrained technological "progress" for the last 150 years. It began with the naturalist-philosopher Henry Thoreau at Boston in the 1830's and found its organized expression at the turn of the century in the Appalachian Hiking Club and the Sierra Club. The first significant discontinuity in the march of progress occurred when the Sierra Club in the late 1890's challenged the City of San Francisco's Hetch Hetchy dam and water project in Yosemite National Park. The Sierra Club finally lost, but its public campaign, which was carried to the President, added significantly to making the naturalists' countervailing world view politically legitimate. Such a political and philosophical tradition appears not to exist in many other countries; it helps to explain the deliberation with which many Californians review "progress."

Dr. Reijnders observes in his paper that "the state has only recently begun to evaluate risks." Risk analysis as a component of public decision making has perhaps assumed a greater role in recent years, but implicitly, at least, public inspectors and insurance companies have for years taken the risk of industrial facilities into rough account. In the US, the former Federal Power Commission since World War II has granted more than 40 certificates for liquefied gas facilities, many peak shaving plants. What is new, as Dr. Reijnders suggests, is the immensely heightened awareness of *formal* risk analysis on the part of decision-makers, industry, and interested parties.

Decision-makers and the processes in which they participate incorporate values in diverse ways. In the US, environmentalists and public citizens have often expressed their positions with respect to industrial facilities in terms of the traditional Anglo-Saxon value system of "rights." In relation to natural systems, a considerable advance was made when a noted jurist found that trees have legal standing in the United States. Thus, people and nature have rights, above all to life, that a LNG facility, for instance should consider and protect. From that narrower perception of "rights" has evolved a much broader claim, e.g., that Americans have a "right" to relatively inexpensive energy. In such a calculus, transoceanic LNG has difficulties fitting into the energy mix.

The application of a doctrine of "rights" in North America raises some difficult issues. The Chumash Indians historically occupied the California coast around Point Conception. For them, as well as many others, the jutting headland there has been reported as the gate to heaven. Should white men despoil the Chumash's sacred site with a mere LNG terminal, or protect their "rights"? State and federal decision makers extensively considered the Chumash's rights and then overruled them. Should the Chumash nation ever return as a political power, the Vatican may not be safe.

Dr. Reijnders notes the existence of competing interests within the energy industry. That helps to explain the multi-dimensionality of US energy policy: in our economically expanding pluralistic system, every significant energy player in the past received a piece of the pie.

In the discussion of the history of risk, in which risk becomes Dr. Thompson's aesthetic experience, we might want to add the very important local dimension of perceived risk. In the United States, in places like Staten Island, Oxnard, and Santa Barbara, the local perception of risk has been informed by proximate, tangible, and easily understood events that became etched into a deterministic appreciation of risk. Past events in the all-too-human hazardous industries suggest "it can happen here" and the puritanical strain in us recommends prudence.

Dr. Reijnders in passing mentions the major role played by the media in the public perception--and, therefore, in representative democracies, political reality--of risk. An Amoco Cadiz on the rocks, a Sansenina at the bottom of the harbor, an El Paso Paul Kayser limping into port, a Three-Mile Island, a Cove Point explosion--they are all telegenically vivid educators of how the public and the political elites perceive the risk of industrial development. In these matters, the perceived is the real, conflicting expert evidentiary hearings notwithstanding.

In this conference, we have predominantly conceived of "risk" in terms of the immediate safety of the facility, surrounding land uses, humans, etc. In the case of LNG importing countries such as the US, and perhaps others, the project-life economic risk (in terms of capital foregone, end use rate costs, etc.), may be equally significant. What administration or regime can long concur in an LNG-contract price spiral as the one proposed by Algeria?

Dr. Reijnders suggests that technical and economic analyses, however well performed, may easily be overwhelmed by other factors in the decision-making process. The California experience (and, I presume, others') tends to bear him out. Supervening actors, with their own motives comprised of political fear and opportunity, overrode the existing California decision-making process to "expedite" the project approval. One example involves the California legislature; the other, the US Air Force. Neither one would have been considered in a risk analysis from an environmental point of view prior to their occurrence.

My final point regards counterexpertise. Dr. Reijnders would hope that we throw our experts into the battle with the applicants'. It may be useful to others to know that in the United States there is a federal statute, the Public Utilities Regulatory Policy Act, which provides for public intervenor funding, provided the intervenor makes a substantial contribution to the case. The California Public Utilities Commission, to its credit, has applied that law recently to reimburse a consumer group for its actual costs for experts and attorneys in preparing and presenting its case. I hope that encourages Dr. Reijnders' "science shops" to continue to participate in the decision-making process, for the issues raised by hazardous industrial development--LNG, nuclear, biotechnology, toxic waste--are too important to be left to the applicants' experts and the governmental regulators alone.

SINCLAIR: As Dr. Salz remarked, we tend to get into this US versus the-rest-of-the-world in practically everything we say. I hope in the remaining discussion we can avoid this. I am also interested in the rebirth of Jeremy Bentham at this workshop. He, in some ways, was responsible for the idea of cost-benefit analysis. One of the major fallacies of cost-benefit analysis, which one often sees in print and hears on peoples lips, is that it implies the maximum good for the maximum number, that it maximizes benefits while minimizing costs. Anyone who has done a minimum of mathematics knows that it is almost always impossible to maximize two factors at the same time, or maximize one and minimize the other. You can maximize or minimize, but you cannot do both. Much of the discussion on cost-benefit analysis was based on this fundamental ignorance of some basic mathematical facts.

KEENEY: An implication that follows from your statement "That trees have legal standing," is that you cannot then have an absolute position for the value of human life. You cannot slaughter millions of trees to save one life, and that *per se* implies that there has to be value tradeoffs somewhere. Obviously, I believe that there must be value tradeoffs.

SHAREFKIN: What I have missed in this discussion is a serious consideration of what would be a good way to design an institution for making decisions. I found one or two attitudes in the discussion here. One is to learn to cope with a hopeless mess; the other is to muddle through. We did not have regulatory agencies 10 years or even 100 years ago, and we probably will not have them in 50 years. At many places in human history people have displayed some ingenuity in devising different solutions to different problems of this kind.

We create rights when we want to give people the right to something that might happen. In effect we have done this in facility sitings in many ways. I would like to see where this is justified. To me a right is something that cannot be violated, or overridden, by majority rule. But experience and formal analysis of collective choice procedures show that the creation of rights and the attribution of rights create a heavy bias towards the status quo. If you insist on unanimity, and you dish out rights liberally, what you are going to have is what you have now.

I think we can set up a set of decision processes in the United States where you do not trade across issues. Once you force a decision on an issue, where you have two sides, then either you have a stalemate or something else. What I would like to see explored are two questions: What would be a sensible set of criteria for giving a local community or some individuals the right to stop a project? And second, what are the possibilities for cooperative solutions or compromises where nobody would feel that he is being ignored?

REIJNDERS: I want to make three points. One is a matter of historical interest. Referring again to the divergence of the United States and Europe. In Europe, the standing of technology has had its ups and downs; technology and people have always been uneasy bedfellows. Environmental concerns have not been high on the agenda in normative discussion in Europe. The second point, which I always find uneasy, concerns the fact that decision analysis requires tradeoffs. But there is a group of people who are saying that the right of life, or even the right of privacy, should be sacred. These, as a rule, cannot be traded off for anything. These rights are viewed as nearly absolute rights, that may only be infringed on in highly exceptional circumstances.

The last point concerns what Dr. Sharefkin has raised. I do not think that rights only freeze the status quo. I think they may work for change, but they are necessarily only preconditions for change. I agree that in practice there is often a strong tendency for rights to gravitate to the status quo, but this depends on the actual system of rights you have in a society.

SHAREFKIN: We are talking about rights the way some people talk about facts. I do not think there are any agreed upon rights, rather rights are just broad principles. We are always dealing with abstract objects. My idea of a right of privacy or a right of life is different than your idea of these rights.

REIJNDERS: You can see that in practice there are different cultures with different rights.

DEUTSCH: Although you can say there are certain sacred rights in society, nobody dealing with problems of the sort found in the siting process could possibly behave in a manner consistent with the idea that there are divine rights inherent in one group that cannot be the subject of tradeoffs.

A LOCAL VIEW OF TERMINAL SITING

P.D. Mehta
Aberdour/Dalgety Bay Joint Action Group

The increasing scale and complexity of our technologies, while often bringing considerable material benefits, are creating new scales of potential disasters. Nowhere is this more true than in the LEG field. Nowhere else is the social impact of an innovatory industry so great and yet so little understood. As multi-national oil companies are poised for a massive increase in the production and use of LEG, few governments are equipped to deal with sensible siting and control of LEG facilities. The Mossmorran/Braefoot Bay development in Scotland is a good case study and is explained briefly in this Paper. The Paper is essentially a representation of the problem as perceived by a local community which is fearful for its safety and explains the attempts which it has made to protect itself in the face of ruthless commercial adventurism and official complacency.

The Paper is in two parts. Part I gives a brief account of Shell/Esso's proposals for LEG facilities in Scotland and the Action Group's campaign against them. Part II considers some general issues highlighted by the campaign.

PART I

THE BACKGROUND

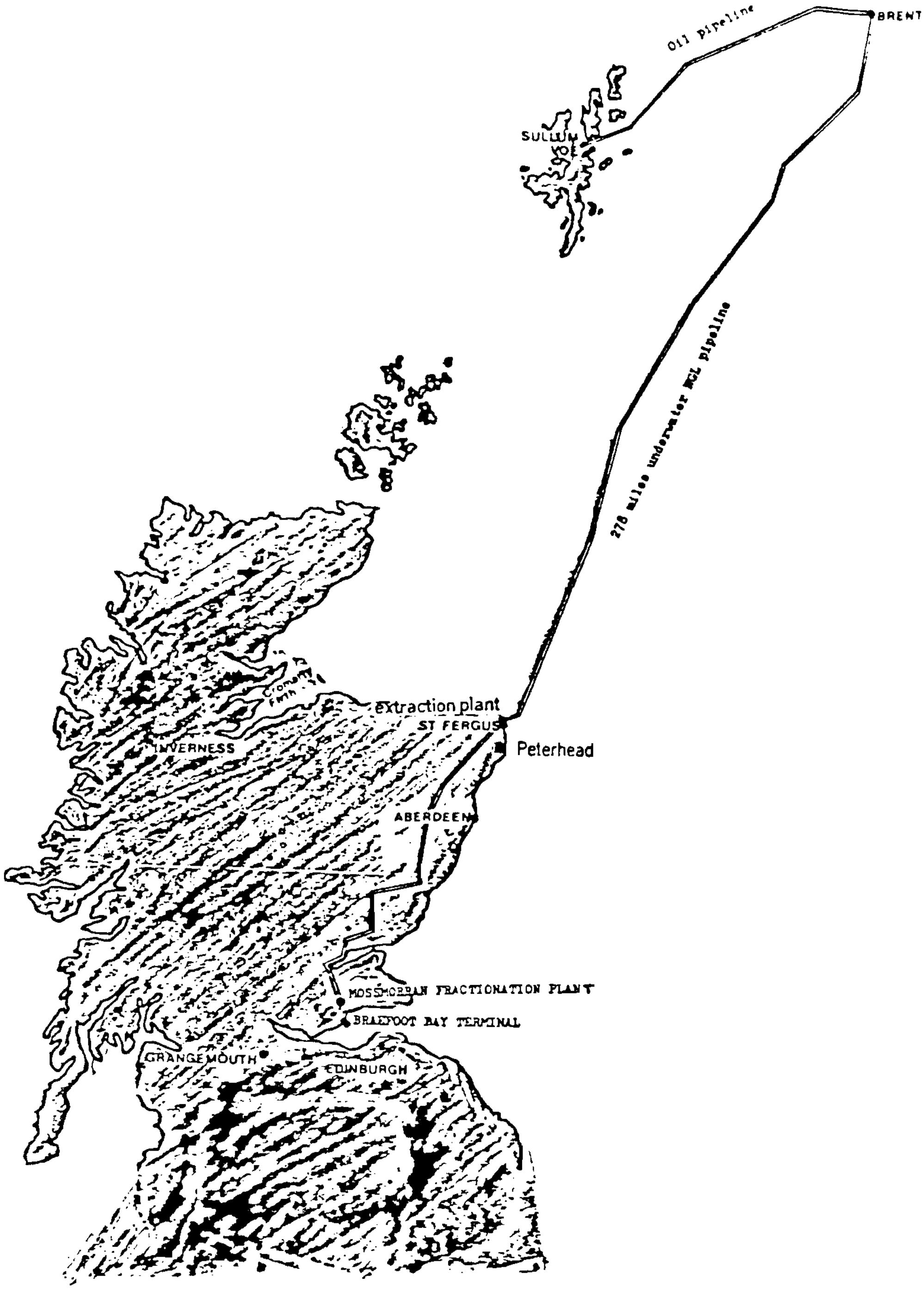
The Shell/Esso proposals for Fife, Scotland, form part of the development of the North Sea oil and gas resources, particularly the Brent field which lies about 115 miles Northeast of Shetland Islands. Brent was discovered in 1971 and, apart from being very rich in oil, was found to have an abnormally high content of natural gas. By 1973, Shell had decided on a pipeline landing point for the gas at St. Fergus, North of Aberdeen, where gas separation facilities were already under construction for the removal of Methane (see Map 1).

However, it was not until 1975 that a planning application was made for an NGL fractionation plant and terminal at a site near Peterhead. In September 1975, the UK Health and Safety Executive (HSE), in a rare expression of prudent safeguarding policy, laid down a siting criterion--that an NGL plant should be sited at least 1 mile from residential areas and 1/2 mile from another plant. That effectively sterilised two thirds of Shell's chosen site and forced them to look for alternatives.

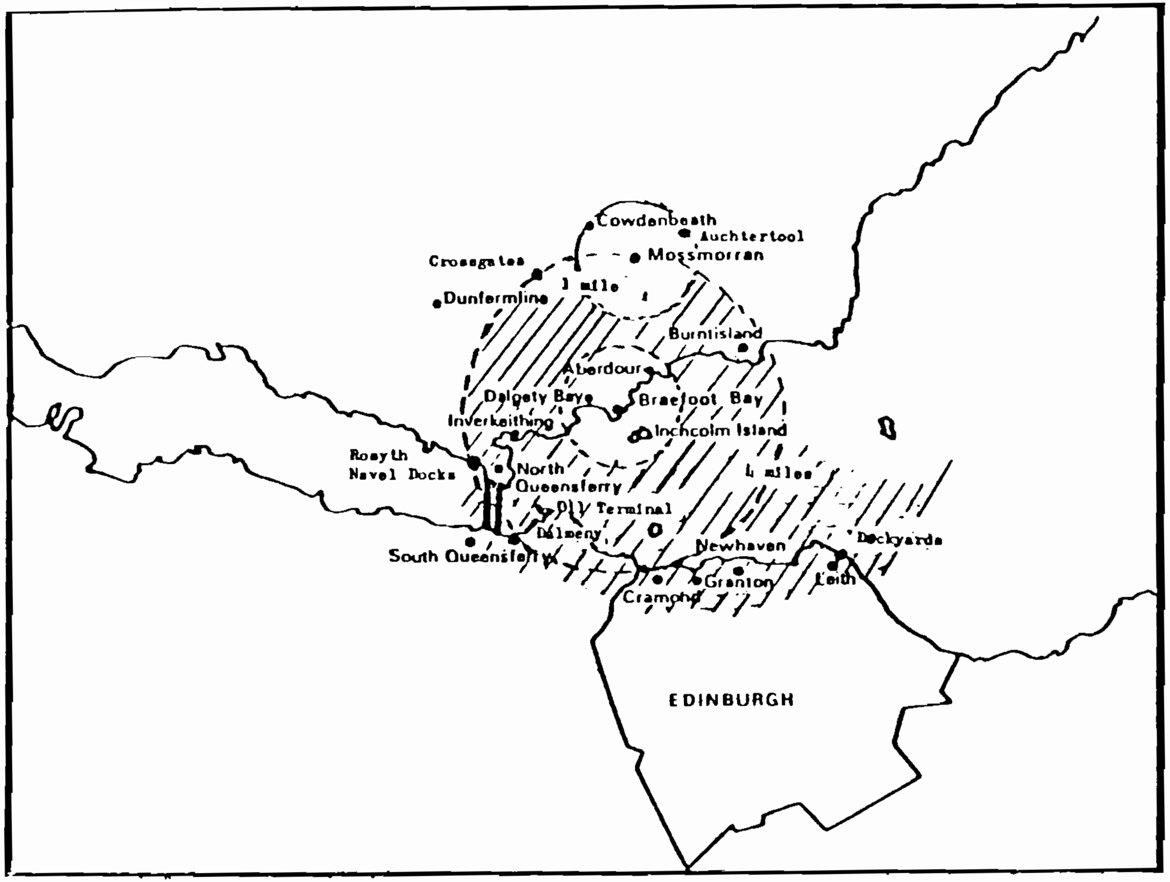
In February 1976 Shell applied for planning permission on a second site at Peterhead with terminal facilities in Peterhead harbour. In support of that application they argued that the NGL plant should be as close as possible to the St. Fergus gas separation plant and that Peterhead harbour was, for a variety of reasons, an ideal safe port, well able to cope with the LNG traffic even when the harbour is developed to its full potential. But the local fishermen were not convinced. Local opposition led to a public inquiry which opened in May 1976. Part of the way into the inquiry Shell was forced to withdraw their plans when their Dutch computer told them that conditions occasionally occurred in the North Sea which made Peterhead harbour unsafe to handle ships with hazardous cargo--a secret hitherto known only to the local fishermen and sailors for centuries.

A new site search was hurriedly undertaken and within two months of withdrawing from Peterhead, Shell/Esso had found new sites at Mossmorran/Braefoot Bay in Fife, 135 miles south of the St. Fergus plant. Formal planning applications followed in early 1977. Lured by prospects of downstream industries and a job bonanza, the plans were enthusiastically welcomed by the local authorities and politicans. They were also welcomed in the town of Cowdenbeath, near Mossmorran, which suffers considerably from high unemployment. But they were bitterly attacked by informed residents in Aberdour and Dalgety Bay, two villages about 1/2 mile on either side of the Braefoot Bay terminal site with a combined population of about 7,000.

As indicated on Map 2, there are approximately 30,000 people living within about 1 mile of the Mossmorran/Braefoot Bay sites. The capital City of Edinburgh is approximately 4 miles from the shipping lane which will be used by LEG tankers. Within 4 miles (6 km) of the operations, there is an existing population of over 100,000.


BRENT
Oil pipeline
278 miles underwater NGL pipeline
Cromarty Firth
extraction plant
ST FERGUS
Peterhead
INVERNESS
ABERDEEN
MOSSMORRAN FRACTIONATION PLANT
BRAEFOOT BAY TERMINAL
GRANGEMOUTH
EDINBURGH

MAP 1


Cowdenbeath
Auchtertool
Crossgates
Mossmorran
1 mile
Dunfermline
Burntisland
Aberdour
Dalgety Bays
Braefoot Bay
Inverkeithing
Inchcolm Island
Rosyth
Naval Docks
North
Queensferry
4 miles
Oil Terminal
Dalmeny
Newhaven
Dockyards
South Queensferry
Granton
Leith
Cramond
EDINBURGH

MAP 2

THE PROPOSALS

The NGL will be piped under pressure 135 miles from St. Fergus to Mossmorran. At Mossmorran there will be a fractionation plant with a capacity of 2.1 million tons per annum, an ethane cracker of 500,000 tons capacity, and storage facilities for 150,000 tons of propane, butane and natural gasolene. At Braefoot Bay there will be facilities for refrigeration and storage of ethylene (storage capacity: 15,000 tons) and two jetties for export of ethylene, propane, butane and gasolene. Annual LEG ship movements are estimated at 250. The facilities between Mossmorran and Braefoot Bay will be connected by refrigerated pipelines for propane and butane and ordinary lines for ethylene and gasolene. The pipelines will run underground for a distance of about 4 miles and cross two busy roads and a railway line.

THE OBJECTIONS

It would be true to say that the initial motivation of most (although by no means all) of the objectors was a concern for the environment and amenities surrounding Aberdour and Dalgety Bay. However, as the implications of the proposed developments gradually began to be better understood, safety questions began to loom larger and by the time of the public inquiry in June 1977, safety was by far the predominant issue. After the inquiry the safety debate continued even more fiercely, to the exclusion of all others. Concern about property values has never been a motivating factor since we do not believe that property values will be significantly affected.

As time went on we also became increasingly alarmed at the way that safety questions were being fudged or suppressed, and by the performance of the official regulating authorities as well as by the enormous commercial and political pressures that were at work to push the project through without an open or adequate debate.

THE PUBLIC INQUIRY

It is not possible to review here the technical evidence on hazards that was before the inquiry but suffice it to say that the analyses produced by the oil companies and by consultants employed by the local authorities (who were deeply committed to the project) were superficial and reflected the interests of those parties. Those analyses have been the subject of strong public criticism by Prof. J. Fay of M.I.T., who has stated that the analyses would not even get through the front door of an authority in the US. Amongst other things, the reports failed to identify the main hazard to the local communities, namely an Open Flammable Cloud Explosion (OFCE) and the possibility of radio break sparks from a nearby transmitter causing explosions at the Braefoot terminal. Hazards from LEG shipping--the most likely area for accidents--were barely mentioned. The input by the Health and Safety Executive (the official agency responsible for safeguarding public health and safety) was even more superficial and useless. Their evidence to the inquiry is reproduced in Appendix 1 without further comment.

Although the objectors had very little time within which to prepare their evidence for the inquiry, they were very fortunate in obtaining the services of Professor D.J. Rasbash and Dr. D. Drysdale of the Fire Engineering Department of the University of Edinburgh. These independent expert witnesses highlighted the hazards of OFCE to Aberdour and Dalgety Bay, estimated the probabilities and also put forward a fully reasoned case why the risk of death to the surrounding community must have a probability of occurring of less than once in a million years. On the evidence available, they concluded that the risk would be significantly greater and recommended that the terminal be moved to a more remote site.

That standard of safety (1 in 1 million) was not challenged by any of the parties at the inquiry and specifically acknowledged by the Health and Safety Executive and the Inquiry Reporter as being a reasonable norm. HSE has subsequently found it inconvenient to be tied to any such numerical factor in judging the risk of an operation and prefer a "flexible" approach. However, the Reporter, in recommending approval of the development, as he did, clearly assumed that the plant can be designed and operated to that safety standard. The Minister, in granting approval to the development, has failed to confirm any such standard of safety. The Reporter's recommendation was also based on a number of other assumptions which subsequent evidence has shown to be incorrect or inconsistent but the Minister refused even to consider these matters when making his final decision.

POST INQUIRY INFORMATION

In the period between the public inquiry (July 1977) and the Minister's approval of the planning permission (August 1979), the Group was able to acquire much more information and evidence about the hazards of LEG and submitted the same to the Minister and to the HSE. With one relatively minor exception, all this information has been completely ignored by the Government. As far as they were concerned, the question of safety was covered at the inquiry in 1977 and the debate was closed.

I will not elaborate upon the additional information as you will all be familiar with it, but will simply mention the major items:

1. G.A.O. Report 1978 (1)
2. O.T.A. Report 1977 (2)
3. 1977 California State legislation and the preceding sub-committee Report (3)
4. Canvey Island Report 1978 (4)
5. Groningen Risk Assessment Study for Eemshaven (5)
6. Shipping Hazards Report for Braefoot Bay by the Action Group, as to which see further information below
7. Unconfined Vapour Cloud Explosions by Dr. K. Gugan (6)
8. A catalogue of the continuing disasters in the oil/gas industries, particularly involving shipping and including Qatar, Abqaiq, Abu Dhabi, etc.
9. In September 1978, Prof. Rasbash warned the Government that further research made him very concerned about the harrowing possibilities of fire and explosion that could occur if water gets inside an LPG tank following a relatively minor shipping incident. His research indicated that the 1975 IMCO Standard for construction of LPG tankers (7) actually visualises the puncturing of tanks and their becoming filled with water as a design feature for the stability of the ship.

GROUP'S SHIPPING HAZARDS REPORT*

The Group had been pressing for some time for a quantitative risk assessment on the plant and particularly on the marine hazards which had received less than cursory treatment. Since there seemed to be no intention on the part of the companies or the authorities to do anything other than a superficial and meaningless assessment of the risks, scientists within the Group carried out their own quantitative evaluation of the consequences of a major spill of LPG or ethylene arising from a shipping accident at the Braefoot terminal. The evaluation used the methods developed by the Safety and Reliability Directorate (SRD) of the UK Atomic Energy Commission and applied in the Canvey Island Report (4), making due allowances for differences in wind/weather conditions, traffic, topography, etc.

The report was ready in January 1979 and was submitted for verification to independent consultants, Dr. J.H. Burgoyne & Partners, London. The consultants advised that although there were some areas in which they had reservations, in general the assessment had used the methods and data of

* A more detailed summary of the Report is given in Supplementary Paper No. 1.

the Canvey Report in an appropriate way. They also agreed that even after making the appropriate adjustments, to take account of their reservations, the preliminary estimates of the probability of a serious accident causing multiple deaths at Aberdour and Dalgety Bay were significantly greater than published official opinions on what constitutes an acceptable risk, and justified more detailed studies before irrevocable moves are made in relation to the terminal development.

The Group's Report, as verified by Burgoynes, shows that the risk of each individual in Aberdour/Dalgety Bay being killed as a result of a shipping accident at the terminal is of the order of 1 in 1,000 per year. The chances of a serious accident causing multiple injuries in the Forth are as high as 1 in 300 per year. That compares with the finding of the Inquiry Reporter that no individual outside the plant should be exposed to a risk of injury (not death) greater than 1 in 1 million per year. The Report also examined and found significant risks to other communities on both sides of the Forth, including Edinburgh. It is important to remember that the Report only assessed the risks of a shipping accident at the terminal jetty; other accidents such as at the shore installations or a collision or grounding along the shipping lane, will make the risks even higher.

The Report was sent for critical comment to the Minister, HSE, Shell and SRD, but none has so far made any comments. SRD were at one stage prepared to review the Report at a fee which the Group was prepared to pay, but SRD's offer was subsequently withdrawn because of constraints imposed upon them by HSE!

The Report was also sent to Mr. V.C. Marshall (a member of the Advisory Committee on Major Hazards), Director of Safety Services at Bradford University, who also confirmed that it uses in a correct manner the methodology of the Canvey Report in reaching its conclusions. He appealed to the HSE in the interest of open government to publish the information upon which their own judgement was based if they wished to rebut the Report's conclusions.

RADIO FREQUENCY IGNITIONS

Break sparks from radio waves or electromagnetic radiation can create a hazard of ignition or explosion near gas installations in the event of gas leaks (8). This hazard was completely overlooked by Shell/Esso, HSE and the local authority consultants despite the fact that one of the main sources of radiation is a radio transmitter which is only a few meters from the terminal site at Braefoot and the pipelines leading to it.* The hazard was first brought to light by scientists within the Group after the public inquiry.

Although coming after the inquiry, the Minister acknowledged this to be relevant new evidence and called for further representations on the subject to be sent to him by all parties. It should be remembered that the Government was at that very time severely embarrassed by a similar situation which has arisen at Crimmond where a multi-million pound NATO base could not be fully utilised because of a similar ignition hazard to nearby gas facilities at St. Fergus. This relatively minor and somewhat esoteric hazard thus became the one and only question raised since the public inquiry that the Minister was prepared to listen to. All the other items of additional information mentioned earlier were ignored by him.

The HSE made three different attempts over a period of about a year to try and explain away this hazard. Each of their three reports was severely criticised by the Group's advisers and shown to be so full of errors, omissions and discrepancies as to be quite unreliable as a basis for any safety judgement. The HSE eventually shelved the problem to be looked at again--after the plant has been built. There seems little doubt that if the full extent of the military radio and radar transmissions in the Forth are admitted, they will exceed the minimum safe levels. This subject is too technical to cover in a brief paper such as this but the problem has been fully documented and the papers can be made available to anyone interested.

THE PLANNING APPROVAL

In August 1979, the Government granted planning permission for the Fife project subject to a number of fairly innocuous conditions. The most important of the conditions are meant to be that:

(1) A full independent hazard and operability audit in relation to the design and construction of the NGL feedline within the site, NGL plant, product pipelines and terminal facilities shall be carried out to the satisfaction of the Secretary of State prior to the commissioning of the plant, and

(2) Operation of the Mossmorran and Braefoot Bay facilities shall not be commenced until such time as any measures considered necessary by the Secretary of State have been carried out to deal with any possible effects of radio transmissions.

*It is now conventional wisdom that that particular transmitter must be removed from its present location.

It should be noted that there is no definition of what the audit is, what form it will take, who will carry it out to ensure its independence and, above all, what standards are to be satisfied. Moreover, shipping--the most likely source of a disastrous accident--is not covered. The second condition pre-empts the whole question of what electro-magnetic field strengths and levels of power induced in site structures might be, and whether effective steps can be taken to prevent dangerous levels. It also presupposes that naval traffic in the Forth can be compelled not to use certain frequencies of transmissions for fear of creating dangerous break sparks.

At any rate the whole concept of a safety audit that is not carried out until after the plant is built at a cost of several hundred million pounds of both public and private capital is absurd. Moreover, the planning conditions are so vague that it is extremely doubtful if they can in law be enforced in the event of any disagreement.

PART II

THE GREAT UNCERTAINTIES

There must be few areas of applied sciences where there are so many unknown aspects and where even the experts disagree on so many of the most fundamental questions. Indeed the only area of scientific agreement appears to be on the lack of research and reliable experimental data. No one for example knows for certain how LEG clouds will behave in a large spill; how far they will travel within the flammability range or indeed what that range is; in what circumstances they will form a fireball or detonate; what the resulting blast effects or burn zones will be; whether even the most modern tank designs can withstand the massive internal pressures caused by little understood phenomena such as roll-over or ice-blocked valves; to what extent can knowledge gained from small-scale laboratory experiments be extrapolated with any confidence to the massive scale of applications in practice.

By way of illustration of the above the following additional points might be made:

(1) The maximum extent of the flammable LNG plume following instantaneous spill of 25,000 cubic meters of LNG on water has been estimated by various authorities as ranging between 0.75 miles and 50.3 miles (9)

(2) Shell is currently undertaking trials in the UK on the release and ignition of LNG and LPG up to 20 tons. Shell Research has said, "The research programme has reached a stage where instrumented tests of a medium scale, equivalent to a medium sized road tanker load, are needed to validate details of mathematical models." One wonders when they will be able to determine what a 1,000 ton spill on water, particularly of ethylene, is likely to do.

(3) It was not until Flixborough (1974) that process designers and plant operators became fully aware of what an unconfined vapour cloud explosion was. Such explosions have in recent years become the predominant cause of the largest losses which have occurred in the chemical and petrochemical industry (10).

The Advisory Committee on Major Hazards in their first Report (11) were prompted to write following Flixborough, "We are unhappy about the lack of knowledge in some areas. We know there is an absence of basic data on the behavior of massive releases of toxic and flammable gases." Recent pronouncements from the HSE would seem to suggest that they now know all there is to know about the hazards--see, e.g., Appendix 1.

(4) It was not so long ago that we had quoted to us Shell's plant at Qatar as a fine example of a well designed modern plant incorporating all the fail-safe devices known to technology, and which Shell had just completed building. Indeed it was understood that Qatar was to be a prototype for Fife. And yet Shell must have known at the time that the storage tank or tanks at Qatar had been causing problems shortly after the plant was commissioned in 1975. In April 1977, shortly before the public inquiry opened in Fife, the plant in Qatar was virtually destroyed, killing all on site. While there has been no public explanation of the causes of that disaster, Shell has stated that they have now changed the tank design so that the same thing can never happen again. One must assume that the latest tank design is also largely experimental and that there is no real experience of the capacity of a second concrete wall and bund to withstand the pressures of a catastrophic failure of the storage tank or an explosion following a minor gas leak.

(5) Perhaps the greatest uncertainty of all is provided by the virtual certainty of human failures somewhere along the line in the

conception, design, construction or operation of advanced technical projects, particularly those such as LEG which are at the forefront of technological innovation. Quite frequently the prime cause of disasters is not inadequate technical knowledge or skill but elementary human error or negligence by otherwise responsible experts and operatives (12).

All these grave uncertainties are not a sufficient reason for an absolute ban on the use of these hazardous substances. But they are a very good reason for remote siting of bulk storage and transport facilities--which is the conclusion reached by most independent studies such as those carried out by G.A.O., O.T.A., The Rand Corporation, and the California State Assembly. In imposing strict siting legislation in 1977, the California legislators said, "LNG safety is at such a primitive level that risk assessment studies can at best produce crude estimates little better than a wild guess. Until we know much more about the hazards of large-scale LNG operations, such facilities must be sited away from population centers in order to minimize public risk.

PROBLEMS OF MONITORING

It is a paradox that the difficulties of monitoring technology are greatest precisely where the needs are greatest, i.e., in the highly innovatory large-scale projects such as LEG facilities and particularly at the design stage. The difficulties are intensified by the fact that the requisite technical competence is often monopolised by a few individuals and institutions who are already committed to an advancement of those technologies. However, independent assessors are not always impossible to find as I think our own input into the LEG safety debate in Scotland has demonstrated. But then they generally lack political power or voice and can all too easily be ignored in the face of enormous commercial and political pressures in support of new developments.

By far the most serious defect in the social control of advanced technology is the weakness of the regulatory authorities. To be effective a regulatory authority must have adequate resources, expertise, professional competence, teeth, and above all, independence. Our experience in the UK has clearly shown that the regulatory authorities are gravely deficient in all these attributes. They are in no position to challenge the ruthlessness of the great corporations and are reduced to making cosy compromises with industry in the firm belief that industry knows best what it is doing. As the Council for Science and Society has explained in their admirable publication "Superstar Technologies," a monitoring agency that lacks power will soon lose its independence and then become subservient to those it is supposed to be regulating (12).

In the aftermath of the Flixborough disaster the Advisory Committee on Major Hazards stated, "with the kind of operations that these plants deal with we cannot afford to have a situation where industry operates on a basis of trial and error. We are equally conscious of the fact that while developments in manufacturing technology have raced ahead, the methods of ensuring safe operation, indeed the appropriate legal mechanisms for enforcement of safe standards may not have kept pace." In reality, the situation in the UK today is no better than it was before 1974 despite the great bureaucratic edifices that have evolved following Flixborough.

QUANTITATIVE ASSESSMENT OF RISKS

As with most other major questions concerning LEG, there is considerable controversy about quantitative risk assessment studies for LEG facilities, particularly in the US. The G.A.O. Report concluded that risk assessment studies have not reached a stage where they give confidence in their conclusions. In Holland, they seem to have encountered no insurmountable difficulties in using quantitative criteria, be it in the assessment of the height of dikes (13), or the safe-siting of an LEG terminal (5).

In the UK, SRD have carried out a detailed quantitative evaluation of the risks from petrochemical installations in Canvey Island using techniques which they have developed over a number of years in both nuclear and non-nuclear fields (4). The investigation was described by HSE as unique and as an example to companies of how such hazard evaluations ought to be carried out. They agreed with SRD that "the quantitative approach was the most meaningful way of comparing different risks.... To express risks in numerical terms provides one with a common denominator, a method of putting various risks in perspective and comparing them with each other." (As with other pronouncements, HSE appears since then to have changed their tune on this question.)

There are, of course, well recognised weaknesses inherent in a quantitative assessment, particularly where historical data are lacking. But even allowing for these weaknesses, a quantitative assessment is far more meaningful than a subjective and qualitative description of a risk as being "very remote" or "not high"--or to say, as Cremer and Warner did, that an accident involving a loading arm at the jetty was "the least improbable" of events.

I submit therefore that quantitative estimates of risks are essential to any safety debate. A judicious use of such an approach, however approximate and tentative, is a logical and useful tool which at least indicates whether you are in the right magnitude band or league for acceptability or not. That is what our Shipping Hazards Report attempted to do and which revealed that the risks were of such magnitude that at the very least, further investigations were essential before the facilities were allowed to be constructed.

ACCEPTABILITY OF RISK

The acceptability of risk is another concept which has been the subject of considerable controversy. It would be presumptious of me to attempt to elaborate the arguments at a conference such as this. What seems to me to be incontroversible is that at least when dealing with the risk of multiple deaths to a community that derives no direct benefit from a major hazard installation, we must have a yardstick for judging whether the risk is acceptable. Not to have such a yardstick is to have no standards at all. From the point of view of the public who have the risk imposed upon them, they need to be protected both from those who create the risks and from those who are supposed to monitor the risk makers. To do otherwise is to relegate the vital issue of public safety standards to the vagaries of the market place and subject to manipulation through the political and commercial pressures that are always at work.

What then should these standards be? As we saw earlier the HSE in the UK and other parties at the public inquiry into the Fife plant acknowledged that the risk of serious injury to the public from an industrial undertaking should not exceed 1×10^{-6} per year. The Advisory Committee on Major Hazards in their first Report stated that if a serious accident was unlikely to occur more often than 1×10^{-4} that might perhaps be regarded as just on the borderline of acceptability. In the Canvey Report, the HSE appears to be setting a criterion of acceptability of a risk of death as high as 1×10^{-4}. They have been severely criticised by other authorities for doing that, and rightly so in our view.

In a more recent paper, Prof. D.J. Rasbash has proposed that a community of some 10,000 people should not be exposed to a risk of fire disaster that would kill more than 100 people from an activity from which they do not derive any direct benefit or to which they are neutral, more often than 1×10^{-7} (14).

The Province of Groningen in Holland in approving the development of the Eemshaven LNG terminal in 1978 using a hazard assessment carried out by the Dutch Research Organisation (TNO), laid down absolute limits of acceptability as follows:

(1) An accident capable of causing 10 deaths is unacceptable if it has a probability of occurring more than 1×10^{-4} years.

(2) An accident capable of causing 100 deaths is unacceptable if it has a probability of occurring more than 1×10^{-6} years.

(3) An accident capable of causing 1,000 deaths is unacceptable whatever the probability of occurrence.

(4) The risk to individuals is unacceptable if it is worse than one chance in 100,000 (5).

On the basis of the foregoing it seems to me that the criterion of acceptability of a risk of multiple deaths to the public should in general be no higher than 1×10^{-6}. When considering a new plant in a greenfield site with a capacity of causing more than 100 deaths, the criterion should arguably be even lower, say 1×10^{-7}.

But whatever criterion is used, it is axiomatic that there is a clearly defined standard of acceptability so that we can judge whether a proposed plant is at least in the "correct league of magnitude" or not.

On the evidence available, the proposed terminal in Fife is nowhere near the correct league of magnitude even by the standards which the authorities have acknowledged as being reasonable, let alone the higher standards which prudence would seem to dictate.

It should also be pointed out that in the UK there are no guidelines or legislation governing the exposure of the public to industrial hazards. The only directly relevant legislation is the Health and Safety at Work Act 1974 which imposes a general duty on plant operators to conduct their undertakings in such a way as to ensure that "so far as is reasonably practicable" employees, as well as the general public, are not thereby exposed to risks to their health or safety. That is, of course, no standard at all. The administration of the legislation is the responsibility of the Health and Safety Commission and their executive arm, the HSE. The Commission is dominated by sectional interests, particularly by industry.

The HSE, as indicated above, lacks the resources of finance and expertise and are quite ineffectual as a monitoring agency. Which perhaps all goes to explain why we have a system of "self-regulation", cosy compromises and lack of clear cut safety standards or policies from which the concerned public might take some comfort.

THE DECISION MAKING PROCESS

In the UK, the forum in which local interest groups can air their views about a proposed development is the public inquiry which is generally held before a decision is taken on whether planning permission should be granted for the development or not. It should also be noted that the construction of a LEG facility in the UK requires no more than an ordinary planning permission as required for any house or other building.

Public interest bodies have through bitter experience come to regard the public inquiry system with increasing cynicism if not outright contempt. There are many reasons for this, chiefly:

(1) There is great disparity in the resources available to the participants leading to unequal representation. It is difficult to match the resources of multinational oil companies by collections made from door to door and at jumble sales.

(2) Complex scientific or technical questions cannot be adequately debated in an adversary situation, particularly where the participants are of unequal strength.

(3) The inquiry can only make recommendations which the Minister is free to disregard, and often does, for reasons which may not have been open to discussion at the inquiry.

(4) The Reporter/Inspector who presides at the inquiry is essentially a civil servant and his independence is questionable.

(5) Most governments regard public participation in planning to be no more than a token gesture to democracy.

Furthermore, a Minister's decision on planning is not subject to appeal on the merits of the case. Planning decisions are regarded as administrative exercise of ministerial discretion and as such cannot generally be challenged in the courts. A government Minister can thus impose on the public severe risks of death and injury and yet his decision cannot be questioned and no criminal liability attaches to him.

The whole of the planning and legal processes in the UK are thus quite ill-equipped to deal with the grave social implications of large scale technological developments particularly where public safety is involved.

THE RESPONSIBILITY GAP

As the G.A.O. Report has fully explained, because of the corporate structures of the various operatives involved in an LEG facility, and the deliberate creation of a multiplicity of companies and interests with limited liabilities, it is very difficult to pin-point responsibility for disasters and therefore to obtain compensation or redress. In a major disaster, the assets and the liability insurance of the culprit are almost certain to be far from adequate. Moreover, for a third party--particularly for members of the public--it would be virtually impossible to establish negligence on the part of any of the operatives. Serious jurisdictional problems can also arise because of the international nature of the operations.

The major corporations who are behind large LEG projects and stand to benefit most, are thus protected by corporate and legal veils from full responsibility for disastrous accidents that might kill or injure thousands. All of this tends to diminish incentives on safety, particularly under pressures of time and economies. Thus local communities who have the hazards imposed upon them also have to carry, to a considerable extent, the financial risks of disastrous accidents. The Bantry Bay disaster in Ireland which killed 50 people is a good example. Eighteen months after the disaster the relatives of the dead and other victims have received no compensation while Gulf and Total blame each other for responsibility.

What is required urgently, is a system of absolute liability whereby the parent corporations who are behind the LEG facilities, are held responsible for all damage and injury caused to third parties as a result of the operations and <u>irrespective of whether negligence can be established</u>. The companies would need to show that they are able to carry the financial burden of such liability or to make arrangements for adequate insurance cover. If the risk to the public is as remote as the companies would have you believe, they should have no objection to such a safeguard and no difficulty in obtaining liability cover. That would also give them better incentives for safer operations and help to reduce situations like Bantry Bay.

TIME FOR EFFECTIVE ACTION

It is perhaps encouraging that there is a growing concern in many countries about the hazards associated with LEG. The European Commission recently issued a draft Direction (COM (79) 384) aimed at major accident risks where it is proposed that manufacturers will be required to produce detailed hazard analyses. Even the HSE have issued (some 5 years after they were set up) draft regulations for notification of certain hazard installations.

We might be forgiven for feeling that all this is no more than tinkering with the problem. The real problem is not so much identifying where the hazard lies, as what should be done to impose effective controls on the hazardous operations in order to protect the public. There is more than enough scientific material and experience to clearly indicate the nature of the hazards. What we require is urgent action to minimise the hazards, and above all, prudent and sensible siting criteria for new LEG facilities as the only sure way of reducing the risks to the public. Both scientists and public policy makers have an important responsibility in that regard.

It has very recently been announced that Shell are now proposing to increase the size of the feedline from St. Fergus to Mossmorran from 16 inch to 24 inch. That will inevitably increase the amount of LEG that will be processed, stored and shipped in Fife. The risks, which in our view are already far too high and unacceptable, will consequentially be even greater.

CONCLUSIONS AND RECOMMENDATIONS

1. LEG is a valuable natural resources which will increase greatly in availability in the very near future. However, storage and transport of large quantities of LEG pose enormous dangers and require urgent and concerted action to minimise risk to the public.

2. LEG technology is in its infancy and urgent research work is required to throw light on the many fundamental uncertainties. Until our knowledge and experience of LEG has increased greatly, remote siting is the only prudent safeguard.

3. Governments must impose a safety zone or cordon sanitaire of at least 4 miles (6 km) around LEG facilities, particularly around terminals and shipping lanes. In countries where such remote siting policy is impracticable, the companies must be required to develop off-shore facilities for which technology already exists (3).

4. A detailed hazard survey must be carried out by independent assessors with the requisite skills, BEFORE any decision is taken on approval of an LEG facility. A sensible sequence in the evaluation of a project is shown in Appendix 2 which is reproduced from the Groningen study (5).

5. Major risks of an LEG facility must be assessed in a quantitative manner for which techniques are available and becoming more sophisticated. Such an approach will at least indicate whether a risk is in the correct league of magnitude for acceptability and provide a logical basis for comparison with other risks.

6. There must be clearly defined standards of acceptability of risks. The criteria should be similar to those adopted by the Province of Groningen (as presented earlier in this paper).

7. Companies who are responsible for introducing the hazards and operating the facilities must accept absolute liability for all damage and injury that may occur as a result of the operations.

8. It is dangerous to leave industry to regulate itself in matters of public safety. At the same time the system of monitoring must be greatly improved to prevent the monitoring agencies from becoming subservient to those they are supposed to monitor.

REFERENCES

(1) U.S. General Accounting Office, Report to the Congress of the United States, Liquefied Energy Gases Safety, July 31, 1978, EMD-78-28.

(2) U.S. Office of Technology Assessment, Transportation of Liquefied Natural Gas, September 1977.

(3) California State Legislature, Assembly Sub-Committee on Energy, Liquefied Natural Gas Hearings, 1976/1977. California Legislation, Section 5582.

(4) Canvey--An Investigation of Potential Hazards from Operations in the Canvey Island/Thurrock Area, HMSO London 1978.

(5) Criteria for Risks Related to Dangerous Goods, Nota Milieunormen -- Provinciale Waterstaat Van Groningen, May 1978.

(6) Dr. Keith Gugan, Unconfined Vapour Cloud Explosions, Institute of Chemical Engineers (UK) 1979.

(7) Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, IMCO, London, 1976.

(8) BS 4992: 1974, Guide to Protection Against Ignition and Detonation Initiated by Radio Frequency Radiation. See also draft revision document 76/27631 BC, September 1976.

(9) U.S. Coastguard (Department of Transportation) Predictability of LNG Vapor Dispersion from Catastrophic Spill on Water. An Assessment (Washington D.C., April 1977).

(10) J.A. Davenport -- A Study of Vapor Cloud Incidents -- 83rd National Meeting of American Institute of Chemical Engineers, March 1977.

(11) Health and Safety Commission, Advisory Committee on Major Hazards, First Report, 1976, HMSO, London.

(12) Superstar Technolgies -- Report of a Working Party -- Council for Science and Society, London 1976.

(13) D. Van Dantzig -- The Economic Decision Problems Concerning the Security of the Netherlands Against Storm Surges.

(14) D.J. Rasbash -- Criteria for Decisions on Acceptability of Major Fire and Explosion Hazards with Particular Reference to The Chemical and Fuel Industries -- I. Chem. Symposium No. 58. See also (15).

(15) D.J. Rasbash -- Review of Explosion and Fire Hazard of Liquefied Petroleum Gas, Fire Safety Journal, 2 (1979/80) 223-236.

APPENDIX 1

ETHYLENE CRACKING PLANT AND DOWN-STREAM DEVELOPMENTS
ESSO CHEMICALS LTD, MOSSMORRAN, FIFE

STATEMENT OF EVIDENCE BY D.V. OFFORD, HM Senior Chemical Inspector of Factories, Health and Safety Executive.

1. The outline proposals for the construction and operation of an ethylene cracking plant adjacent to an NGL separation plant at the Mossmorran site have been carefully considered.

2. No details of size or type of plant have been provided by the firm so that it is only possible to say, at this time, that providing the cracking plant, which presumably involves no new technology, is designed, constructed, installed, operated and maintained to currently acceptable standards there should be no reason to suppose that the plant will present an unacceptable risk either to people working on the site, or beyond the site boundaries.

3. Proposals for down-stream developments have been referred to but no definite selection of specific processes has yet been made. When such selections are submitted care will need to be taken to ensure that each proposal is viewed according to the risk. Any down-stream developments should meet current design and safety standards and sufficient separation in-plant and from the boundaries should be provided.

4. All installations where flammable liquids, gases and vapours are stored and used at elevated temperatures and pressures will give rise to some residual risk which cannot be completely accounted for either by location or safety precautions. Consequently, further safeguards should be provided in the form of additional safety separation, a cordon sanitaire, around the site. In my opinion the residents of Gray Park should be rehoused away from the area before the proposed Ethylene Cracking or NGL Separation plants become operational.

5. If the Local Authority approves the firm's outline proposals, then careful consideration of the detailed proposals which will subsequently be forthcoming, will be necessary. Any such proposals will need to meet the requirements of the currently accepted standards as referred to in paragraph 2 above.

DVOfford
13.6.77

Appendix 1 (continued)

STATEMENT OF EVIDENCE BY DR. R.V. FOSTER, HM Chemical Inspector of Factories
SHELL UK Exploration and Production Limited, Mossmorran and Braefoot Bay, Fife

NATURAL GAS LIQUIDS PLANT

General

1. I have studied some of the documents relating to the proposals by Shell to erect a plant for the separation of natural gas liquids (NGL's) at Mossmorran, with export facilities at Braefoot Bay. These include the Environmental and Hazard Survey, and also the Report on the Hazard and Environmental Impact, prepared by Cremer and Warner.

2. All of the materials involved in the processes are highly flammable, and it is therefore of the utmost importance to prevent a flammable concentration in air of the vapours from reaching a source of ignition. This can be achieved by good containment, plant separation, and vigorous control of all ignition sources.

3. Hazards may arise due to two main causes, namely failure of equipment, and of operations. Risks from the former may be minimised by careful attention to design and maintenance, whilst good housekeeping and operator training should reduce the risks from the latter. I think that Shell have shown that their design teams have considered every possible source of risk in the equipment, and have incorporated the necessary safeguards to counter them. Similarly, one may expect that operating procedures and operator training will be to the highest standards in the light of the Company's experience in these fields.

Potential Hazards

4. The areas where hazards due to equipment failure may arise can conveniently be divided into two, namely the processes, and the storage. Hazards connected with the pipelines, and with the harbour operations are discussed elsewhere.

Processes

5. In the process plant, the materials are all at temperatures above their normal boiling points, and are under pressure. Failure may conceivably occur at pumps, compressors, flanges in pipe work, or furnance tubes. Such failure will inevitably result in the release of hydro-carbon vapours to atmosphere, and these may well reach a source of ignition. However, the inventories of the individual items of plant are relatively small, and the size of a vapour cloud will be correspondingly small. In addition, the individual items or plant can be readily isolated, and feed stock diverted to other vessels, or flared off under control. Attention to design and strict maintenance schedules should ensure that catastrophic failure of these items of plant will not occur in practice, so that instantaneous release of the contents of any vessel is not considered to be a credible accident.

Storage

6. Three products will be stored at this site, propane, butane, and gasoline. The first two of these will be stored as refrigerated liquids, whilst the gasoline will be stored at ordinary temperatures. Because these materials will all be stored at ordinary atmospheric pressure, the likelihood of tank failure is remote. In addition, the NGL's are all non-corrosive, and hence will have no deleterious effect on the materials from which the storage tanks will be constructed. Failure of a storage vessel in service is a rare event, and to my knowledge, there have only been three instances involving refrigerated NGL's. These have all occurred with single walled vessels, protected by an insulation layer on the outside. The proposals for storage of refrigerated products at Mossmorran are for double integrity tanks, that is to say, they will be constructed with two concentric walls of special steel. The product will be contained in the inner tank, and the outer tank will be insulated on its outside surface. Thus vapour from the chilled product will permeate the annular space between the two tanks, and the fixed roof will be above the outer shell. In the event that the inner shell will fail, the outer shell will contain the full contents of the tank, but will clearly have to be designed so as to be capable of withstanding the full hydrodynamic force resulting from such a failure. The Shell submission provides for outer bounds of a minimal capacity, in fact capable of holding approximately 10% of an individual tank's contents, this capacity being commensurate with the maximum theoretical leakage arising from 1/4 gasket failure on the largest pipe below the liquid level in the tank.

7. The tanks will be provided with high temperature, pressure, and level alarms. Remotely-operated shut-off valves will be provided on all lines below liquid level, and where appropriate, valves will be interlocked to prevent inadvertent product mixing. All tanks will be provided with pressure relief valves, which will be discharged safely, generally to the flare system. The relief system will be of sufficient capacity to cope with over-filling, variations in atmospheric pressure, or a failure of the refrigeration systems. Failure of the refrigeration equipment associated with the low temperature storage would result in a very low rate of evaporation of the stored product. This is because the insulation of the storage tanks is such that heat transfer from the surrounding atmosphere is minimal, so that the rate of evaporation of the tank contents would also be minimal, and well within the capacity of the relief system. Day to day variations in atmospheric pressure would be dealt with by the refrigeration equipment, but under abnormal conditions, the relief system would be designed to deal adequately with the maximum rate of vapour boil-off.

8. Fixed water sprays will be provided on the storage vessels, so that cooling water can be applied to any tank or tanks in the event of a fire occurring at a neighbouring storage vessel. In addition, portable monitors will be provided, and can be operated from strategic positions.

The Effects of Leakage of Flammable Materials from Storage

9. The possibility of catastrophic failure leading to the release to atmosphere of large quantities of flammable vapours is one that may properly be considered to be remote. Small leaks, which could in theory become aggravated so as to involve other items of plant may occur, but the risk from these may be reduced to small proportions by the use of sound practice in the design and materials of the highest quality in the fabrication of the plant. The risk from small leaks which are the consequence of normal wear and tear on plant may be greatly reduced by good maintenance and housekeeping.

General Conclusions

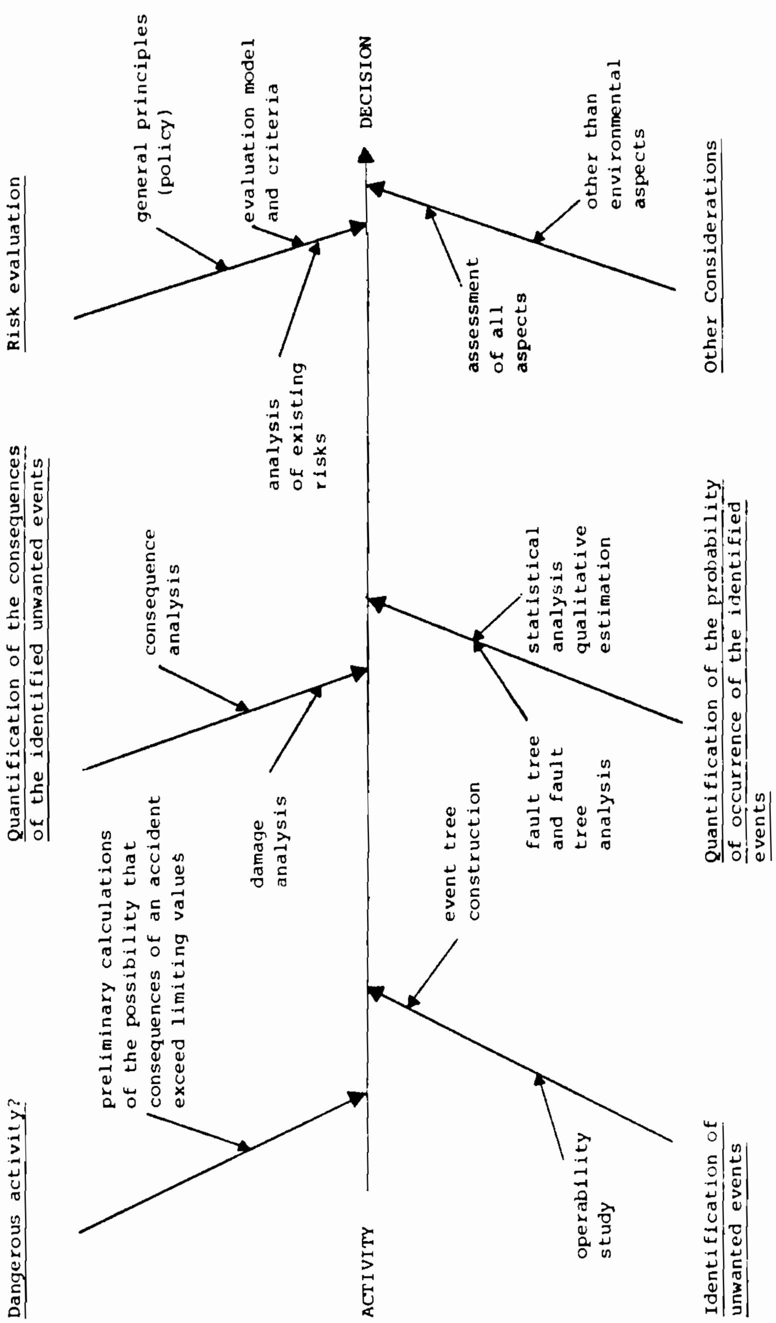
10. It is my opinion that provided the process and storage are designed, constructed, maintained and operated to the highest standards currently available in the petroleum industry, there will not be an intolerable situation imposed on the surrounding neighbourhood, and there need not be any insuperable objections to these proposals.

11. The proposed site for the erection of a NGL's separation plant at Mossmorran is well separated from existing industrial developments. However, a housing estate at Gray Park is only 800m from the site boundary, and would be approximately 1300m from the process area, 1000m from a refrigerated LPG storage tank, and 900m from a gasoline storage tank. It is my opinion that these separation distances are questionable, and that the residents of this estate should be rehoused away from the area before the NGL's separation plant is built.

R. V. Foster.
13 June 1977

APPENDIX 2

Schematical Review of the Assessment and Evaluation Procedure.



See Also: "Discussienota veiligheidsproblematiek van de provinciale waterstaat van Zuid-Holland" d.d. feb. 1977.

SUPPLEMENTAL PAPER # 1

SHIPPING RISKS AT BRAEFOOT BAY

Summary

The need for hazard and public safety assessments in the siting of major industrial developments is generally accepted, but their conduct and application in practice is capricious and ends up satisfying no one. This article reviews the safety aspects of the petrochemical development at Mossmorran and Braefoot Bay, and particularly risks associated with the accidental release and ignition of LPG and ethylene during shipping movements, which illustrate the inadequacy of the present approach.

In the Beginning...: The Background

In January 1977, Shell and Esso submitted planning applications to the Fife local authorities for the construction of an LPG separation plant and an ethylene cracker at Mossmorran, near Cowdenbeath, and an export terminal for the two plants' products at Braefoot Bay, midway between the village of Aberdour and the new town of Dalgety Bay. The applications were called in by the Secretary of State for Scotland, and a Public Local Inquiry convened in June 1977. The Inquiry Reporter recommended approval of the proposals in November of that year, and the Secretary of State gave his provisional approval in April 1978, confirming the go-ahead in August 1979.

Prior to the Inquiry, the local authorities commissioned an independent assessment of the impact of the proposed developments by a consultant firm, Cremer & Warner, experienced in the petrochemical field. In the safety section of their report, they adopted a qualitative approach which identified possible failures and classified their probabilities coarsely as low, very low, or negligible. Possible consequences in terms of injury to the public were not discussed in any depth. The report covered shipping up to the point of failures during cargo loading, but not navigation risks and their consequences. Cremer & Warner concluded that the construction and operation of the plants would not significantly impair the safety of the public at large, subject to incorporation of specific precautions which they judged to be necessary and practicable.

At the Public Inquiry, the HSE concurred with the Cremer & Warner conclusion, though their evidence in chief suggested a much more superficial assessment - their written submission prior to the Inquiry ran to a mere four pages of text. Once again, no reference was made to the dangers of shipping movements, nor to the possible consequences of an accident, however remote its probability of occurrence. Expert witnesses for the oil companies and also for the objectors to the development (who were predominantly but not exclusively residents living near to the Braefoot Bay terminal) argued the technicalities of the behaviour of heavier-than-air vapour clouds and the likelihood of vapour cloud spillages detonating in unconfined conditions. In these discussions, spillages of 10 to 15 tonnes of product were projected.

Tables of Stone - The Canvey Report

The Secretary of State's final decision was delayed by 21 months because of a protracted debate by report and counter report over the risks of spillage ignition by radio transmission - a risk totally overlooked at the Public Inquiry despite the expertise there deployed. During this time, in the middle of 1978, the HSE's £400,000 study of the various hazards in existing and projected installations at Canvey Island on the River Thames was published. The HSE introduced it as unique - the most thorough study of its type hitherto published - and proffered it as a model on which the safety of other major hazardous installations could be assessed and judgements made on the cost-benefits of any changes which might be called for. The detailed analysis which forms the substance of the report was prepared by the Safety and Reliability Directorate of the UKAEA, and their basic approach was to identify every possible failure or accident, quantify its probability of occurrence, and estimate its potential for causing danger or injury at a number of populated areas surrounding the Canvey installation.

Because Canvey dealt with both existing and projected developments (and incidentally was used to justify changes to the design of the latter), the Braefoot Bay objectors saw no reason why the same sort of analysis could not be applied to the Shell/Esso proposals, and indeed great merit in so doing. If the risks introduced by the proposed developments could be quantified, they could be compared with known voluntary and involuntary risks which already existed and judgements made as to the acceptability of the plants on safety grounds. There would undoubtedly be differences of opinion about the question of acceptability, but at least a debate on this point could be made on a reasonably sound basis, rather than purely on the grounds of emotion or instinct.

In the event, the objectors requested a Canvey-like study; the HSE saw no reason why this should be necessary and the request was refused.

For Those in Peril on the Sea - Shipping Risks

An analysis of the content of the Canvey Report shows two factors of interest. Firstly, in its consideration of spillages due to accident, Canvey deals not only with 10 or 15 tonne quantities, but also with spillages in the multi-thousand tonne range. Any consideration of spillages of this magnitude at the Mossmorran Inquiry might have thrown quite a different light on the debates about explosion and conflagration and their potential for causing injury or death. Secondly, and perhaps more important, the report showed clearly that by far the largest contributor to the total annual risk to both individuals and groups of individuals living near Canvey arises from spillage of products from ships, and not soley, as considered at Braefoot Bay, during the loading operation, but during berthing, unberthing and transit between the jetties and the main shipping lane up and down the Thames.

These shipping operations included the transport of LPG, and it occurred to Mrs. Nancy Rice and myself that while we had no significant knowledge of the shore installations proposed, the shipping operations at Braefoot Bay could not differ in qualitative terms from those at Canvey. It therefore seemed reasonable that we should attempt an "amateur" Canvey-style analysis tailored to Braefoot Bay to see what order of magnitude of risk emerged, and that we should offer the analysis up for the HSE and other experts to pick holes in.

The process of the analysis is fundamentally simple. Canvey identifies three types of accident causing rupture of a ship's product tanks, and arrives at a probability for each type of accident. The annual incidence of spillage is then readily calculated from a knowledge of the annual traffic to the petrochemical complex. In examining the possible consequences of hydrocarbon spillages, Canvey divides the latter into two categories, those of ignition at source and of drift of unignited vapourised product to a remote source of ignition. The probabilities of each category are assessed and assumptions made about the effects in terms of numbers of injuries and/or deaths in particular areas. The total risk to individuals and to groups of individuals per annum is obtained by multiplying the probabilities of spillage occurring by the probabilities of assessed injury for each category and adding the two together.

The transfer of the Canvey model to Braefoot Bay presents several problems. Some are relatively easily solved; for example, Met. data is readily available for the area in question and the size and movement data of the shipping traffic is available in total terms from the Public Inquiry evidence. It is a matter of some surprise that Shell were unable to specify the mix of ships within the total traffic figures they had given in evidence, but other Inquiry evidence enables a reasonable breakdown to be deduced. Rather more difficulty arises from the fact that Canvey does not consider ethylene at all (since ethylene is not a product of the Canvey complex) and hence no base data was available to us. Ethylene differs from LPG and LNG, both of which were discussed in Canvey, in three respects: it is midway between LPG and LNG in density, and therefore in the behaviour of its vapour clouds, it is midway between the two products in its boiling point, and therefore has undefined (to us) effects on containment materials, and it is more prone to detonation rather than conflagration than either LPG or LNG.

Despite these difficulties, we thought that a useful analysis could be made with the knowledge available to us, and a report was issued in November 1978, with an extended and refined second version following in December of that year. Before looking at the conclusions of the reports, it is worth giving some consideration to the way the Canvey model and its assumptions were applied, and the potential weaknesses within the calculation. In combined scientific/policy topics such as this, it is often the practice for authors to advise "lay" readers to skip the technical element as being too complex for them and to look only to the conclusions. I do not support this approach; I believe that non-technical people should understand that the basic mathematics of hazard calculations is no more difficult than that involved in many an income tax return, and certainly less than that required to understand a Company's annual balance sheet. I also think that people should be capable of distinguishing "fact"--if such exists--from informed opinion.

Bespoke Tailoring - The Adapted Model

The Braefoot study confines itself to large product spills only; large ultimately turned out to be 400 tonnes upwards. These spills can only originate from rupture of one or more ship's tanks, arising as a consequence of fire or explosion on board ship; collision or stranding; or escalation of a minor spill due to the cyrogenic effects of the spilt product on structural material in the hull. Canvey (as the Canvey report is known to its diminishing circle of friends) quotes probability figures for each of these types of accident. The incidence of fire and explosion on board ships was based on historical data, and we saw no reason why this probability should differ just because a ship was sailing through Scottish waters rather than English. Canvey's collision probability was an amalgam of historic PLA data for all traffic, and for tanker traffic only, with worldwide data from Det Norsk Veritas. It was thus not transferable to the Forth, where annual traffic is much less, reducing the probability of ship-to-ship collisions. On the other hand, the navigational approach, involving a 140° turn across the tide and the prevailing wind in a rock strewn channel, does not give great leeway for mistakes, and the wind, which has a much more significant effect on liquefied gas carriers than on oil tankers and cargo ships generally because of the formers' high freeboard and low displacement-to-size ratio even when loaded, is generally stronger. In the absence of authoritative data, we used the Canvey probabilities, while recognising this to be purely arbitrary; the tabulated results show clearly the collision contribution to risk and an expert critic has noted that even if collision is totally ignored, the aggregate risk figure is not significantly reduced. The third factor, escalation of minor spills, applies only to ethylene carriers, since the LPGs are loaded and transported at temperatures of -40°C and above, and none of these temperatures normally causes steel embrittlement. Canvey quotes a probability for this type of accident related to methane (LNG), whose boiling point is -160°C; to make some allowance for the intermediate ethylene boiling point of -105°C; we arbitrarily halved the Canvey probability.

The ship traffic information provided at the Inquiry gave only the numbers of LPG and ethylene carriers per year and the range of sizes of each. To decide how many ships would be capable of releasing a given tonnage of product from one tank or from all tanks, a mix of ship sizes was required, and as noted earlier, Shell could not provide this. For the LPG ships, we knew from the Inquiry the total plant output and the market split between the USA, Western Europe and the UK, and assuming the larger ships would be used on the longer routes, a practicable mix of ships was derived. For the ethylene ships, once again the plant output was known but no market information was available (Esso have still, three years after the Inquiry, to make a formal commitment to build their cracker plant so perhaps this is not surprising). The basic approach was therefore to assume three sizes of ship - large, medium, and small - and assign numbers to each which would satisfy the total annual output. From a survey of current shipbuilding, it appeared that smaller ships had an average of four separate tanks each, and larger ones, five.

There is clearly a large element of guessing (or judgement, depending on one's view of one's own capability) even in calculating the probability of accidents which forms the first half of the hazard analysis. This element of data reliability is recognised in Canvey, which categorizes its data in four ways: from a) - soundly based, directly related and generally accepted, through b) and c) - perhaps inferred data from closely parallel results, or extrapolation beyond the range of accepted data, to d) - inspired or informed guesswork. In our case, some of the less reliable data could have been strengthened with the right resources; for example, it would have improved the total reliability of the calculations if Shell's and Esso's own shipping mixes had been available. Judgement data lifted straight from Canvey might also be questioned; Canvey assumes that LPG ships are not as safe as LNG ships, although most newbuilding of LPG carriers seems to incorporate the same type of separate internal containment tanks as the LNG carriers.

The remainder of the risk calculation deals with consequences. We accepted without question Canvey's probabilities of ignition and nonignition of spilled product at source for the various types of accident. For ignited spills, Canvey gives two alternative relationships between the size of spillage of hydrocarbon and the range at which blast overpressure capable of causing injury or death will occur. Unfortunately, it is not made clear whether the gas is LNG or LPG; the latter has a higher explosive potential. Again, it does not give ranges for ethylene, which is more explosive still. Professor Rasbash, of the Fire Research Centre at Edinburgh University, has suggested a relationship between explosive force and flame propagation speed, and by a combination of different mixes of all these variables, a range of spill sizes which could cause these potentially fatal overpressures at Aberdour, 1.5 kilometres away from Braefoot Bay, and at Dalgety Bay 1.75 kilometres away, was calculated for both LPG and ethylene. Mid-range values were arbitrarily selected for use in the hazard analysis, and the number of ships capable of causing such a release from rupture of one and rupture of more than one tank tabulated. Together with the ignition probabilities and the tank rupture probabilities, one half of the total annual risk was calculated.

For unignited spills, the analysis reduces to selecting a model for the dispersion of heavier-than-air vapour clouds. This is a field rich in theoretical tours-de-force and almost totally devoid of any supporting practical experiments, especially where large scale releases are contemplated. In the case of Aberdour and Dalgety Bay as considered in our initial study, it matters little whose predictions are selected, since all place both communities well within the range of flammable mixtures of both LPG and ethylene, and there is general agreement that an ignition source is certain to be found by a drifting cloud in any populated area and that fatalities would ensue. Thus on the simple view we adopted, given that the Met. data which determines the proportion of time in which each community is downwind of a spill at Braefoot Bay is of the highest reliability, the calculation of the second element of the total risk is uncontroversial.

In two supporting notes, we undertook a more refined analysis of the risks due to unignited vapour clouds at Aberdour and Dalgety Bay, and an extension of the study of other Forth-side communities, including Edinburgh. In the Aberdour and Dalgety Bay case, we considered the uniform dispersion of releases in zero wind conditions, and dispersion in light airs to which the Met. authorities assign no direction. Both these aspects involved the use of a gravitational dispersion equation used in Canvey, and our own interpretation of what the short term directional spread of light airs might be. This note also considered the plan form of a dispersing cloud in a more realistic way than Canvey, which added to the calculated risk. That there is additional risk from this last source is not in doubt, but its magnitude depends on the dispersion model used and certainly is. Our second Supplementary Note, dealing with more remote communities, from 4 to 10 kilometres away, is totally dependent on dispersion model and while the model we used was that recommended at Canvey (that of the Americal Petroleum Institute), there are certainly experts who dispute its validity, both as over- and under-estimating the hazard range.

Lead Balloon - The Impact of the Analysis

Our Braefoot Bay Report showed the probabilities of injury or death to individuals living in Aberdour to be in excess of one in a thousand per annum, and about two thirds of that figure in Dalgety Bay. For the Forth-side communities, the probabilities at Burntisland and South Queensferry were of the order of one in ten thousand per annum, and for the remainder, including Edinburgh, around one in a hundred thousand.

The probability figures in Canvey are said by the HSE to be uncertain by a factor of perhaps two or three times, but not ten times; that is, the "true" probability of accident may be three times more or less than the calculated figure. I believe this is optimistic, and would put their uncertainty at an order of magnitude, or factor of ten. Because Mrs. Rice and myself are uninformed in petrochemical terms, our own figures might be in error by two orders of magnitude, or a hundred times. To get some feel for the uncertainty, we therefore submitted our initial report to consultant scientists J.H. Burgoyne & Partners for an opinion. This opinion confirmed the rigorousness of application of the Canvey method, while raising some questions about the relative safety of ethylene ships compared with LPG ships the explosive power of ethylene, the relevance of Canvey ship collision figures to the Forth, and the interpretation of the results. In place of individual risk, the consultants calculated the probability of an accident capable of causing multiple deaths at Aberdour and Dalgety Bay, including their own assumptions on the questions they had raised, and produced figures comparable to our own.

Our full report, together with the consultant's critique, was published on 17th January 1979. The response was immediate and deafening. The Secretary of State acknowledged receipt. The HSE consulted the SRD (who wrote Canvey) and declared them not competent to comment because of differences of topology and Met. conditions between Canvey and Braefoot Bay. The SRD declined our request for their own independent criticism, on the grounds that they had a contractual relationship with the HSE and they feared a conflict of interest. The local authorities said nothing. The oil companies said likewise.

How Long is a Piece of String?

Let us suppose that our report had been treated seriously, or better, that the HSE had commissioned their own authoritative study of the Braefoot Bay shipping operations. This gives us the length of string. But how long is too long - more formally, by what standards should we as a nation have measured the predicted risks to decide on the acceptability of the development?

There are several yardsticks, none of which is of any statutory significance. In his report, the Public Inquiry Reporter recorded that the HSE and Cremer & Warner agreed that the general public ought not to be subjected to a risk of an accident capable of causing injury or death, greater than the risk of being struck by lightning - by common consent, about one in a million. At a Public Meeting in Aberdour earlier this year, Dr. Jack Taylor of Shell Expro said he thought that the plant ought to be no more dangerous than that same lightening bolt.

Trevor Kletz of ICI, writing in New Scientist, reports the UK chemical industry as taking risk reduction measures if risks are in excess of 1 in 200,000 per annum, though as his figure is strictly expressed in terms of the working lifetime of chemical employees, perhaps one should quadruple this for people at risk 24 hours a day rather than the more usual 40 hours working week. Again, these are voluntary risks, so involuntary risks should be at the very least well over 1 in a million.

The Major Hazards Advisory Committee of the HSE suggested that a probability of accidents capable of causing death of 1 in 10,000 per annum was on the boundary of acceptability. Lord Rothschild, writing in "The Listener," quoted risks of 1 in 3,200 per annum for quarry workers, and suggested that perhaps involuntary risks might reasonably be lower than that figure. The provincial government of Groningen in Holland adopted an interesting sliding scale, in which accidents capable of causing ten deaths ought to have a probability not exceeding 1 in 10,000; over a hundred deaths, not exceeding 1 in 100,000, and of a thousand deaths, complete unacceptability.

Shutting the Stable Door? - The Current State of Play

In introducing this article, I said that the application of hazard assessment techniques was capricious. What, then, has happened in the Braefoot case? In announcing his approval for the developments, the Secretary of State said that his concern for public safety was overriding and would outweigh any considerations of national interest. This is of course absurd as a precept, but we may charitably take it as a serious indication of concern about safety. To assure himself that safety was a prime consideration, he required by a Planning Condition that the developers conduct a Hazard and Operability Study before the plant was to be permitted to start operation. This study will be carried out by a consultant to be appointed by Shell, will cost over £100,000 and will analyse the plant's construction, in Shell's words, "down to the last nut and bolt." It will be completed by the end of 1981, and a summary will be published, subject only to considerations of commercial confidentiality. It is not agreed yet whether the study will be quantitative or not.

Shipping movements will not be included.

At about the same time, a Hazard Analysis, which is apparently different from a Hazard and Operability Study, and will cover the shipping movements separately, is to be carried out, or is under discussion, depending on whether one listens to Shell or to the HSE. However, only the Study is required to be to the satisfaction of the Secretary of State. What is not known is what cerebral process the Secretary of State will use to decide whether he is satisfied or not by its findings. Nowhere in any correspondence or published documentation is there any statement of any standard which will be used to assess this satisfaction. Confidence in plant safety is necessary for the peace of mind of the workers and seamen who will operate the plant and ships, of the surrounding public, and of the man who must make the final, possibly fatal, decision. Can this Planning Condition give this peace of mind? And if not, does it mean anything at all?

A secondary protection might be thought to be the Health & Safety at Work Act of 1974. This lays on the operators of a plant a duty to take "all reasonably practicable steps" to ensure the maximum of safety. There is an immediate problem in understanding who is the operator in a ship-to-shore operation, but that need not divert us from the more serious problem.

What is more significant is that an opportunity which is "reasonably practicable" before the first sod is cut, such as the choice of another site, is not likely to be anywhere approaching reasonably practicable when £400,000,000 has been invested in plant construction. If this cynicism, or perhaps rather, realism, is questioned, consider the HSE's April 1980 comment on the proximity of a new and very popular leisure centre to the route through Irvine Harbour, in Ayrshire, taken by ships carrying explosives from ICI's long established plant at Ardeer. "When this complex was first thought about there was no duty to consult with the HSE on safety matters. There is no doubt that we would have advised that the Centre should not be built where it is. However, we have to live with it." (The speaker, of course, doesn't.)

In the Braefoot case, there is a duty to consult, but no such advice has been given because no solid information exists. With diffidence, I point out that there is in fact a hazard analysis of sorts - the one discussed in this article - and the astute reader will have noted that its risk predictions exceed all the possible standards which I have suggested. But is it sensible that any judgement of the viability of a major hazardous commercial development should be based on a study prepared by a mathematics teacher turned mother of four small children and a physicist turned engineering manager working in their week-ends and spare evenings? One would not think so. But perhaps it is more sensible than making a judgment on no information at all.

Conclusion

In writing this article, I have tried to show how a non-expert can understand the process of hazard analysis, and identify the strengths and weaknesses in it. In my experience, while the judgements on basic data may remain the province of experts, the use of those data is not beyond the wit of anyone of average intelligence. It is, after all, the non-expert who makes all the important decisions and gets the boot if things go wrong, and as an engineer I believe strongly in taking any needless mystery out of technical matters.

On the larger question of whether hazard analyses are of use anyway, I conclude that, provided they are quantitative, they do have a value in pinpointing system weaknesses. To achieve their more vital value as decision-making tools, they must satisfy three requirements: they must be timely, they must be as reliable as possible, and there must be a yardstick against which they can be measured.

The time for at least an outline hazard analysis must be before any approval to start building is given. In the Braefoot Bay case, the developers say that even an outline analysis is impossible, despite the fact that no new techniques are involved, until the design is well advanced. I do not believe this; in the electronics industry, we are often required to show that we can achieve specific reliability levels before getting an order, and the ensuing contract calls on us to demonstrate that we have met these levels under financial penalties in the case of failure. This in a field where technology is changing at a terrifying rate, and yet we manage to meet these requirements and survive commercially.

Some elements of a hazard analysis can never be made reliable by experiment. For example, there is no practical way of confirming Canvey's assumption that one release in ten caused by ship collisions will not ignite at source. We can, however, experimentally confirm gas explosion and dispersion models, and this must be worthwhile when some models give hazard ranges 20 times as big as others. It is to be commended that Shell are in fact starting some bulk release tests as I write, with LPG quantities up to 10 tonnes, but more can be done with ethylene and LNG, bigger quantities and different weather conditions.

The yardstick is the ultimate problem - by far the hardest. There can be no absolute go/no go figure; I suggest we need to start with a basic acceptable probability, perhaps 1 in 10,000 per annum, which needs to be made an order more demanding if an accident can cause, say, 100 deaths, and two orders more for 1,000 deaths, as on the Dutch model. There is one other factor in a yardstick which is less amenable to quantification but which cannot be ignored; the general public good, or the National Interest. This may include a job gain, but related to the general level of unemployment; or increased GNP, related to the general wealth or poverty of the nation; or security, related to international stability. It may be a mixture of all three or indeed other areas of interest, and a substantial national interest should ease the acceptability yardstick in proportion to its magnitude. However, if numerical values cannot be assigned to these intangible benefits (and I am inclined to the view that they cannot) at least a hazard analysis can ask the question "Will this new project impose more risks on its employees and its immediate neighbours than others are already being asked to bear for the same sort of benefit?"

All this begs another question: whether the same national interest could be served at a lower risk at another site. A Public Local Inquiry is of no value in exploring this, since it is a local inquiry, and asks only if a development is acceptable in one particular place. This is a subject of its own, and interested readers are referred to the Financial Times of May 2nd; in my view, however, a Public Local Inquiry is a waste of public and private time and money.

Acknowledgement

This article could not have been written if the Braefoot Bay analysis had not existed. This substantial undertaking was a close and complete collaboration between Nancy Rice and myself, and I wish to ensure that her contribution to that study, and therefore to this article, is fully recognised. To my sorrow, Mrs. Rice decided that family pressures made it impossible for her to participate directly in the preparation of this article, and therefore while we have generally discussed the subject matter, the presentation, statements and opinions are mine. If any view the approach as frivolous, or detect mistakes (there are none to my knowledge) it is to me alone that the criticism should be directed.

J.R. Sutcliffe

Extract from SHIPPING HAZARDS REPORT

HAZARD EVALUATION : FORTH COMMUNITIES **BB/2 : TABLE 2**

LOCATION	SURVEY RANGE (km) From Jetty	SURVEY RANGE (km) Min	BEARING (°TRUE) Span	BEARING (°TRUE) Plume Width	BEARING (°TRUE) Sector	MET. INCIDENCE (%) Stability Cat. D G	MET. INCIDENCE (%) Wind	HAZARD/TRAFFIC Hazard	HAZARD/TRAFFIC Spill Size (tons)	NO OF SHIP CALLS (p.a.) LPG 1 tank	NO OF SHIP CALLS (p.a.) LPG >1 tank	NO OF SHIP CALLS (p.a.) ETH. 1 tank	NO OF SHIP CALLS (p.a.) ETH. >1 tank	HAZARD EVALUATION SPILL FATALITY CHANCE 10⁶ Fire/Expl	SPILL FATALITY CHANCE Coll.	SPILL FATALITY CHANCE Cryo Esc	Ship Calls	Wind Factor	Special Factor	FATALITY RISK (10-6 p.a.)	Total
N QUEENSFERRY (Unscreened)	5.6	(5.1)	240	30	225 to 236	75	4	UNIGNITED VAPOUR CLOUD	600	60	0	75	75	4	5	5	154 164 94	0.03	0.7	3.7 4.6 2.8	11
S QUEENSFERRY (Unscreened)	7.2	(5.8)	220 to 230	30	206 to 235		8		1050	44	16	75	75	4	5	5	142 142 94	0.06	0.85	29.0 36.2 24.0	88
HOUND POINT (Unscreened)	4.5	(3.9)	226	30	210 to 235		7		360	60	0	150	0	4	5	5	210 210 150	0.05	0.1	4.2 8.3 3.7	13
CRAMOND	8.1		165 to 180	30	150 to 195		3		730	60	0	75	75	4	5	5	154 154 94	0.02	1	12.3 15.4 9.4	37
GRANTON	7.6		135 to 188	30	120 to 180		6		1200	44	16	25	125	4	5	5	104 104 56	0.03	1	12.5 15.6 8.4	37
LEITH	9.8		120 to 136	30	105 to 150		4		2100	38	24	0	75	4	5	5	61 61 19	0.03	1	7.3 9.7 2.8	19
BURNTISLAND (Unscreened)	6.3	(4.0)	055 to 065	30	065 to 090		11		530	60	0	75	75	4	5	5	154 154 94	0.08	1	49.3 61.6 37.6	148
A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U	V	W	X

SUPPLEMENTAL PAPER # 2

BRAEFOOT BAY: RADIO TRANSMISSION IGNITION RISKS

Introduction

This note gives a precis of the radio transmission aspects raised in 1978 and 1979 prior to the final planning decision on the Shell and Esso proposals in August 1979. The issue itself is relatively insignificant in relation to the majority of factors explored during the period, but it raises two important questions:

-- given its relative insignificance, specifically emphasised by the HSE in May 1979, why was radio transmission as a risk given so thorough an analysis by the authorities, lasting over 21 months? Would not that time and effort have been better spent in looking at real problems which had received scant study or none at all, such as the risk of spillage during shipping movements?

-- treating the issue as a risk study in isolation, what light does it throw on the quality of advice offered to the decision makers by the HSE (and by independent consultants)?

We do not attempt to answer the first question at all. To us, the matter is incomprehensible, assuming as we do that those concerned were seriously interested in understanding the risk position at Braefoot Bay. On the second question, we can be more positive. In our view, the study shows the HSE to be slipshod and incompetent in carrying out the procedural parts of their studies, and untrustworthy in interpreting the results. A summary of the history of the study follows, which we believe justifies this judgment. If this is a measure of their general performance, no confidence can be placed in any of their advice, and decisions based on it are likely to be faulty in respect of safety.

History

The risk of ignition of spills by radio transmission-induced sparks was raised by the Joint Action Group in January 1978, six months after the Public Inquiry. It had been completely overlooked by the expert witnesses for Shell and Esso, by Cremer and Warner and by the HSE (as it had in the St. Fergus NGL development), and their oversight was excused on the grounds that this source of risk was a new phenomenon. (The appropriate British Standard (BS) is dated 1974.)

Following the JAG's query, a series of reports was produced. The major findings are summarised and the JAG's comments follow.

HSE No. 1.

In March 1978, the HSE produced a single page statement based on the (unpublished) report of P. Excell of Bradford University, acting as a Shell consultant. This stated that if a local IBA transmitter were removed, no hazard would exist. Any problems arising from shipborne transmitters could be resolved by regulation. This statement was issued with the Secretary of State's provisional approval, and it may be inferred that the latter relied on the statement. No indication of quantitative analyses was given.

There was marked reluctance on the part of all concerned to make the Excell Report available to us and we were forced to take the Secretary of State to the Court before he eventually released the Report to us. The Excell Report revealed that calculations using the draft revision to the 1974 B.S. had been carried out only for fixed commercial transmitters. The consultant was less complacent about the ability to discount shipborne sources than HSE. In short, HSE's advice which was based on a report produced by Shell's consultant was not really supported by that report.

In passing, Cremer and Warner also published a report on radio risks at the request of the Local Authority following exposure of the problem by JAG. Its only noteworthy content was a statement that liquefied ethylene was no more dangerous than aviation fuel.

The JAG formally rejected the HSE's conclusions, particularly on the grounds that because the Firth of Forth is a military river, regulatory control of shipborne sources could not be assumed; that the latter would also be of higher power than might normally be expected; and that there was no indication that the special risks associated with ethylene had been taken into account.

HSE No.2.

In July 1978, the HSE produced a detailed quantitative study, listing all the known land-based sources, and a representative set of civil and military shipborne transmitters, the last including L, S, and X band radars (UK designations). It used two sets of safe field strengths, the first from the draft revision to the BS, and a second more rigorous set based on experimental work by Dr. Brittner in Germany. Their conclusion was again that no land-based problem existed, and that any shipborne problem could be resolved, this time not by regulation but by screening.

The JAG responded by criticising the following points:

-- the HSE study did not use the BS methods, without any justification

-- the assumed modulation index for commercial radio transmitters was half the actual figure

-- the modulation assumed for TV transmissions was f.m. only, instead of a.m./f.m.

- -- the field strength calculations for radar used mean powers, whereas the BS calls for peak powers

- -- combined radar effects were ignored, although the BS procedure assumes combination effects

- -- the shipping channel was shown incorrectly on the area map.

Some of the above are trivial; some are major. Cumulatively, they show a careless approach. The study also contained errors in arithmetic, inclusion of sources more than once, and assumptions which the HSE could easily have verified. The Group also showed that the Royal Navy's standard band surveillance radar, and probably the USN's equivalent, would present an ignition risk on their own, and that there was a significant probability of the two radars combining in a typical military formation. They further questioned the practicability of screening the jetty area including the ship itself--the most likely point of significant spillage.

HSE No.3.

In March 1979, following our criticisms of their earlier reports, HSE produced a new set of results. These used a completely different set of field strength ignition levels. In this report, the processing of radar parameters had been corrected, although the communication transmitter parameters were still incorrect. The position in respect of radars was confusing; references were made to "high-powered," "military," "commercial," "surveillance" and "navigation" almost at random. There were also indications in the report and contemporary HSE letters that the HSE were at different times for and against combination of sources. Again, the conclusion was that no problem existed, using, if necessary, the undefined screening techniques.

The JAG revised the calculations, using the new criteria, with the correct communications parameters. They also noted that the L-band radar which constituted a major risk contributor in HSE report No. 2 had been omitted without explanation in the present report. If included, whether or not combinations of radar effects were assumed, the total transmission level was in excess of the safety level.

In a subsequent letter, the HSE said:

- -- that the L-band radar was omitted because its inclusion would show a hazard, and since the HSE did not believe a hazard existed, it had been omitted

- -- that in any case radio transmissions were not a serious source of spill ignitions, since many other ignition sources existed anyway

- -- that in any case there had to be a spillage to ignite, and it had been proved that this was not credible (it is not known where this has been proved).

Finale

The academic exercise, as it turned out to be, was terminated (not resolved) by the Secretary of State's final approval in August 1979.

J.R. Sutcliffe
September 1980

DISCUSSION COMMENTS

MACGILL: I have a few specific areas that I want to comment on, relating partly to the films we have seen and partly to what Mr. Mehta is saying. I first want to turn back to this question of acceptability of risk, and something came out in yesterday's film. There seem to be two classic cases of acceptably safe activities, one being the totally unknown and the second one being the benefits that are perceived to outweigh the risks. The people of Cowdenbeath, apparently have accepted the plant as safe, perhaps because they do not know what the potential hazards are or perhaps because they perceive the benefits to outweigh the hazards. And the people of Cowdenbeath would probably have something to say if the plant were not to be sited in their vicinity, say on grounds of safety. This seems to raise the questions of who should judge acceptability of risk, and how strong but widely differing views within the communities at risk be reconciled.

The second point I have is on the general accountability of safety. One of the most disquieting features to an "outside" observer about this as a case study is that the public has led the debate on safety. Moreover, this is not a public, national environmental lobby, its local villagers who feel they have to take their own initiative to make sure that certain safety standards are being achieved.

Another main issue that has come up and has been touched on through various discussions is the whole question of loss in confidence in the Health and Safety Executive, the Public Safety Watchdog. This loss in confidence seems to stem from two main issues which may be interrelated. For one thing there seems to be irreconcilable differences in viewpoints (for example on technical matters and on what are adequate safety margins) between some members of the public and members of the Health and Safety Executive. On the other hand, there seems to be accusations of incompetence on the part of the Health and Safety Executive.

As a brief addition to the previous point it may be noted that the HSE adheres to the view that the prime responsibility of safety should lie with industry. However, from the public point of view, the HSE does not seem to be taking enough initiative in the way they carry out their role of public safety watchdog (a difference between safety being achieved and being seen to be achieved).

On the question of public participation, we have two opposing viewpoints about Mr. Mehta and the people he represents. We can either call them "bad losers" who are expressing some sort of desperate reaction to the system because they have not got the result they wanted. On the other hand, we can express sympathy with their cause because they have some legitimate grievances about an unfair decision process (and possibly a "bad" decision).

As a final point, the critical point in the whole decision making process for the local authorities (and the public's elected representatives), came much earlier than the Public Inquiry. Having been convinced at an earlier stage by employment benefits associated with this plant, it may then be much more difficult for them to be convinced by contrary arguments brought up at a later stage in the process. The critical point in any of these siting decisions for each individual party are important to identify.

BARRELL (HSE): I am not going to respond to all the points raised, but would like to repeat the point that both Niall Campbell and I are somewhat inhibited in what we can say because this is still a current issue. Specifically, the pipeline to Mossmorran is the subject of a public inquiry within a few weeks and we will be represented. Hence, there are a lot of things we could say that we are not able to say.

I did notice a couple of curious contradictions in one or two of the things Dick Mehta said. He complained that the Action group had very little time to prepare its case when the planning applications came in, and yet he criticized Cremer and Warner and the Health and Safety Executive for carrying out risk studies on the superficial assessments. I suggest that these are two aspects of the same problem. That there was not too much information available originally, and there was not too much time in which to consider it, caused a problem, which he described. It also caused us a problem. I do not think I would like us to be made the scape-goat for both reasons—because he did not have enough time, and because we were not able to carry out a detailed assessment.

He mentioned that certain technical hazards were raised after the public inquiry. Yet he then criticized HSE for taking a long time to deal with these matters which he suggested was due to incompetence. In fact, it was due to the need to examine these matters thoroughly. It led, in fact, to the publication of three reports. This is hardly a superficial approach to the hazard problem.

He mentioned a Dr. Marshall, who supposedly is a member of the Advisory Committee, and who could not produce any evidence that 15 tons is the order of magnitude which would produce an explosion or detonation. In fact, there is no Dr. Marshall who is a member of the Advisory Committee on Major Hazards. Dr. Marshall is a member of the partnership of Burgoynes whom we commissioned to look at certain matters. There is a Mr. Marshal on the advisory committee, who represents different interests. And the 15 ton concept which was developed by the independent Advisory Committee on Major Hazards, is the best estimate produced by a collection of experts in different fields, none of whom work for the Health and Safety Executive. It is also documented.

KUNREUTHER: I would like to raise the following very general question. How does one balance the cost and benefits between having lower or higher acceptable risks? I gather from your discussion, that you felt a community should have a right to say that they would like a risk below a particular level. What is the basis for their judgment?

CLARENBURG: I would like to add one question to this. How did you get these figures? They are apparently sums of some multiples of risk.

MEHTA: I am not technically qualified to be able to speak about these figures. What I would suggest to you is that you read the full report which I have here and is very technical, along with the paper that I circulated in Appendix 1 which explain the methods we used in arriving at these figures. The report was essentially prepared by independent consultants and a number of other scientists. We do not pretend to be professional risk assessors. These were done by local people with scientific backgrounds, and this is an attempt, in the absence of anyone else, to try and devise at least the order of magnitude of risk that we might have talked about. If we are wrong in any of these figures, we would be quite pleased to correct them. The main point is that a year or more after the report was produced and submitted to all the parties, including the Health and Safety Executive, none of them has ever come back with any sort of comments at all. The report has been ignored.

Taking the points that Mr. Barrell made. As regards the time the parties had for preparing for the Inquiry, I think the main point is that at such an early stage in the procedures, one could do no more than a very brief and sketchy assessment of the impact of the development, but the great difficulty is that there is no procedure whereby a more detailed study can be carried out, in which the public or parties affected can have any say at all. And to the extent that we were able to bring up new information and new evidence, which threw grave doubts on the assumptions that were made in the earlier studies and in the public hearings. All that information was completely ignored by the authorities. As far as they were concerned, the debate on safety was closed.

RAVETZ: Clearly it is nearly impossible to produce adequate analyses within 5 or 6 weeks on any site. The question then is on what grounds did the authorities report the inquiry, and a few weeks later decide to press ahead at that rate, which would certainly leave them open to criticism of trying to rush it through; and then close the door irrevocably.

SINCLAIR: Is it not just in the legislation that you must hear an application within a certain period of time?

CAMPBELL: There is no set time between an application being received and a hearing being held. There is a minimum time which you must allow before a hearing and any extension beyond that is trying to achieve a balance, between providing enough time to make preparations and reaching a prompt decision. Obviously people will disagree whether the right time has been chosen or not.

MEHTA: There is really no such thing as a right time, but unless the information on a detailed plant on which the risk assessment is to be made, is forthcoming, you cannot, in fact, carry out a detailed study. You had a situation at one time where the oil companies were waiting on the sidelines to move in with the bulldozers to start working, and yet claiming that the civil engineering results were not yet available and therefore could not be subjected to analyses. The machinery which they had already ordered, had started arriving on site, before the decision was even made.

I would like to deal with the point that Howard Kunreuther made about the acceptability of risk. I am not proposing that each community that is affected ought to set its own standard of acceptability. Obviously this is clearly not practical. What I am suggesting is that there ought to at least be some generally acknowledged standard, so that the public can judge what standard of acceptability was being implied. Otherwise we get this situation in which the Health and Safety Executive assumes certain standards of acceptability in making the judgment as to whether the plant is safe or not but the Secretary of State refuses, in making his decision, to lay down by what criteria he will be judging the plant to be safe. The whole thing is upside-down since by the time the decision on the safety of the plant is to be made, the plant is already under construction. Then, of course, it is too late. Any doubts on safety ought to be resolved long before planning permission is given, and the plant is constructed.

OTWAY: I would warn Mr. Mehta against agreeing to a numerical acceptable risk criterion, because there is more to life than just not being dead--there are other things that matter besides physical risk. To what extent is this silly numbers game of "acceptable risk" really a surrogate for a debate about the legitimacy of institutions? If the institutions were perceived as being legitimate, then risk should never emerge as an issue. Do discussions of acceptable risk beg the question of institutional legitimacy?

THE CONSTRUCTION OF AN EXPERIMENTAL COMMERCIAL NATURAL GAS LIQUEFACTION COMPLEX IN YEREVAN

Yu. S. Oseredko
All-Union Designing Institute for Gas Industry
Kiev

In the USSR in recent years there has been a trend towards the transportation of natural gas from the sources in the east by pipeline, to new processing centers closer to the major gas consumers in the west of the country.

The output of natural gas has risen to 435 billion m^3/yr, and the length of the transportation pipelines has also increased, so that the necessity of seasonal and short-duration peakshaving has also increased. The most efficient method of controlling irregularities in gas demand is the storage of gas reserves in underground reservoirs. However, the construction of such facilities is possible only in appropriate geological structures or in exhausted gas and oil fields, which may not always be available close to the regions of heavy demand. To control peakshaving, which occurs during the winter period with sudden reductions in air temperatures and malfunctions of the gas pipelines, the most efficient method is to build facilities for liquefied natural gas (LNG), including liquefaction units, isothermal storage units, and regasification plants. Such units are already widely used in the USA, Canada, the UK, West Germany, etc., and in the USSR an experimental commercial complex for the production, storage and regasification of LNG is under construction in the Yerevan region of Armenia. The complex has been designed to control and conserve the gas supply of the area, with a capacity to liquefy 20 tons of gas per hour on 180 days per year. The capacity of the regasification unit is 10 billion m^3/day.

The complex comprises a booster compressor shop, a CO_2 removal unit, gas dryer, natural gas liquefaction unit, LNG isothermal storage facilities, regasification units, and auxiliary facilities necessary for the operation of the complex.

Liquefaction of natural gas at the complex and the storage of LNG in reservoirs is carried out during the six-month summer period when gas consumption decreases. The LNG can then be regasified and transported by pipeline during the 10 or 20 coldest days of the winter. Natural gas from the main pipeline is compressed to a pressure of 1.96–4.9 mPa, and after the removal of CO_2 and drying it is transported to a liquefaction unit. The process of liquefaction is carried out using a cooling cycle with a multicomponent cooling agent (comprising nitrogen, methane, ethane, and propane), with preliminary cooling by propane. The LNG is then taken to isothermal reservoirs, where it is stored at 0.103 mPa pressure at a temperature of $-162^{\circ}C$.

If necessary, LNG can be removed from the reservoirs by immersible booster pumps to high-pressure suction pumps where it is compressed to 5.39 mPa and transported to regasificators with fire heating. The evaporated gas is then heated to $10^{\circ}C$, and is then fed into a main gas pipeline. In addition, gas conservation measures at the complex will be checked under industrial conditions for domestic industry, technological LNG liquefaction processes, storage and regasification necessary to solve problems connected with development of large-scale exports from the USSR. The problems involved in the creation of such large-scale gas complexes have been investigated over the last few years by specialists from the USSR, as well as from other countries. Such a gas complex usually includes: facilities and equipment for exploratory drilling and to prepare the gas for further transportation; gas compression units; a main gas pipeline with compressor stations and cooling units; liquefaction plant with LNG storage facilities; and an LNG terminal.

The most important feature of such a complex is that the majority of the component facilities have to be located in remote, uninhabited areas with severe climatic conditions (prolonged winters with low temperatures, permafrost, tundra, etc.). One of the main problems is that while optimizing technical (design) solutions, facilities also have to be provided for the "on-site" labor force that will operate the complex. One of the easiest ways of reducing the amount of labor required is to install automated and remote-controlled production processes.

A number of preliminary investigations carried out in the USSR have proved that the electrification of large-scale complexes is highly effective in reducing labor requirements as well as in improving efficiency and reliability. Some examples are as follows:

(1) While drilling exploratory wells internal combustion engines are usually used as the main source of power to generate electricity for auxiliary needs such as lighting. However, if an external supply of electric power is used for all processes, then this greatly simplifies derrick arrangements, makes working conditions easier, reduces the labor requirements at the gas field, as well as the amount of motor fuel necessary. Undoubtedly, in this case the labor requirements at the power stations will increase slightly, but if these are designed to meet other drilling requirements, including gas treatment plants for pipeline transportation, processing, hydrocarbon condensate recovery, extraction of valuable components from gas, etc., then the electrification of exploratory drilling is an effective solution.

(2) At present gas turbines are used to drive the main compressors, and electricity is used for auxiliary devices and lighting at gas compressor stations, including those in Arctic regions. Electricity is supplied either from external sources, or from local power stations driven by internal combustion engines or gas turbines.

Analysis shows that the use of electricity at compressor stations for all processes (including gas cooling units to protect the environment) means that all operations can be simplified and also makes full automation and remote control of the plants possible, thus reducing the labor requirements.

If compressor stations are built close to existing or planned power stations, it then becomes economical and therefore profitable to increase the output of these stations in order to supply all the electricity.

(3) At LNG plants, whether in operation, under construction, or even planned, steam turbines are more usually used as the main power source for the compressors and large auxiliary mechanisms. Steam turbine power stations are often built at the plants to provide electric energy needs, (e.g., for small machinery, lighting etc.).

Such siting decisions essentially complicate the operating conditions of liquefaction plants because the process units may be "lost" among the large number of power facilities (steam generators, steam turbines, auxiliary pipeline units, etc.). Therefore, the use of gas instead of steam turbines at LNG plants is more frequently considered. Such a decision is a significant step in the improvement of operation conditions at liquefaction plants. However, with the use of such a systematic solution to the problem, one more step is necessary to allow conditions of plant operation and its efficiency to be improved further and, under certain conditions, to increase the reliability. This includes the construction of a central power station equipped with high-efficiency combined units (STAG) at the LNG plant and the use of electricity only in the plant. In such an example, the delimitation between technology and energetics can be seen very distinctly

If an LNG plant is located within the boundaries of an existing electricity generating system then their mutual reservation and, accordingly, the increased reliability of both the plant and the power system may be achieved in a way that would be impossible if steam or gas turbines were used. Using a liquefaction plant, booster LNG reservoirs are necessary to compensate for the irregular arrivals of methane tankers because of changing nautical conditions. Also, in order to provide preventive inspection and repair the output of each process line and, accordingly, of the whole plant, is a little higher than is nominally required.

Taking into consideration all of these factors, the efficiency of the power system operation may be increased if the liquefaction plant can run at maximum output during breakdowns in the loading timetable of the power system and at minimum output during peakshaving. In the case of Yerevan the necessary capacity of the booster LNG reservoirs should be determined not only by nautical conditions, but also by taking into consideration the joint operation of the liquefaction plant and the electricity generating system, and also ensuring the elimination or extenuation of breakdowns at main pipeline terminal sections at which it is not possible to use the full pipeline capacity, to prevent breakdowns in gas supply during emergencies.

The example of Yerevan shows how wide is the sphere for the application of systems analysis in the design of large-scale gas complexes.

DISCUSSION COMMENTS

NORTON: How large a storage tank are you building?

OSEREDKO: 1080 cubic meter, 3 tons 60 cubic meter.

DALL: In the photograph of the USSR LNG facility model, I notice the tanks are underground. What analysis did you perform to conclude that underground siting of tanks is preferred to above ground?

OSEREDKO: The underground siting was decided upon for two reasons: that of safety and that of economics. The tanks are half underground and half above.

DALL: I notice, in addition, there are no containment systems, no dikes around the pipelines that go from the liquefaction building to the storage tanks. How would you deal with an LNG spill from the pipes or the tanks? Maybe the model is not complete, but it seems to indicate that the grading of the site is such that if there were a spillage of LNG, it would travel downhill through the site.

OSEREDKO: In reality they exist, but they are not shown here.

CAMPBELL: What form of permission is given for the building of a plant? Is application made by the gas company to some local authority for approval or, rather, is it given to some central authority?

OSEREDKO: The government has a 5-year plan in which the development of gas in liquid form is considered, as well as the construction of LNG complex developments.

KUNREUTHER: Could you elaborate on the relationship of the gas industry and the LNG complexes to the 5-year plan?

OSEREDKO: There is a general 5-year plan for the development of the country, and there are specific goals for the gas industry in order to supply needed energy. LNG is one part of this energy plan. The relevant administrative governmental structures include the government state planning committees, the state committee for science and technology, the ministry of gas industry, and certain design institutes. On the basis of this 5-year plan, the ministry gives an assignment to the research institutes to study the siting and economic efficiency of these plants. The results of these studies go to the ministry which then forwards the results of this exercise to the state planning committee. Since this is an experimental complex, these same results are sent to the state committee for science and technology. On the basis of these results the government makes a decision about building the LNG complex.

CAMPBELL: By government, are you referring to Moscow or Armenia?

OSEREDKO: The government to which I am referring is in Moscow. On the basis of these studies, all questions are coordinated with the local government in Armenia and with other land users who will be involved in this process.

SINCLAIR: How long does this process take?

OSEREDKO: It depends on the type of facility. In this particular case, it took from 2 to 3 years since other cities had also been considered as the site for the LNG terminal.

SINCLAIR: At what stage are you in constructing this plant?

OSEREDKO: About 20% of the facility has already been constructed.

SINCLAIR: Can you tell us how far from the nearest town it is located? How is it set into the landscape?

OSEREDKO: Yerevan is at a distance of about 20 kilometers from the site. The nearest village is about 3 kilometers, but it is behind a mountain. Yerevan is also on the other side of the mountain.

BULL: You mentioned that several other locations were considered. What emerged as advantages and disadvantages of the different locations?

OSEREDKO: It was mentioned in my report that there are many factors which influenced the decision making process, including characteristics of the region, itself, along with the irregularities of gas consumption.

BULL: Could you give a concrete example of a possible site which turned out to be too dangerous or a example of an area that competed for the project?

OSEREDKO: During this process, one of the cities under consideration was Moscow, but the site was rejected for reasons of safety. The regulations state that an LNG facility should not be closer than 10 kilometers to a city. Since this complex is experimental, it is important that the safety factor be high. Moscow has many pipelines underground, and it is possible to store natural gas underground in geological formations. Yerevan is not in the center of an industrial development, it does not have its own fuel resources, and there is no possibility to store gas in geological formations.

SHAREFKIN: I am convinced that one of the major forces influencing the reliability of a facility in the United States is the system of liability and insurance. Operators and manufacturers are potentially liable for very large sums of money in the event of an accident. You do not have a system, as I understand it, of private or corporate responsibility. Were there to be a major accident at this time, how would the responsibility and liability be apportioned and secondly, what do you see as the effects of this allocation of responsibility?

OSEREDKO: The responsibility for financial loss is carried out by the Ministry of Gas Industry.

VINCENT: I would like to ask you a more technical question. In France, we are customers of the USSR gas industry, and from time to time, especially in winter, we have noted, from time to time, decreases of the consumption output of the pipe. My question is, does the gas industry in the USSR plan to build additional facilities to fulfill its contractual obligations?

OSEREDKO: I do not know the exact conditions of the contract which provides gas to France. There are a couple of possibilities, one being that you could create this same type of storage plant in France.

ECONOMIC PROBLEMS OF IMPROVING LIQUEFIED GAS PRODUCTION AND PIPELINE TRANSPORTATION*

Yu. I. Maksimov
Institute of Economics and Organization of Industrial Production
Siberial Branch of the USSR Academy of Sciences
Novosibirsk-1980

The USSR gas industry has developed rapidly over the last two decades. This development in 1955–1980 and the proportion of the industry in the national power-fuel balance, are shown in Table 1 (Baybakov 1979). In 1955 the proportion of gas in the USSR power-fuel balance was insignificant (2.4%), but by 1960 this had increased more than threefold, and in 1960–80 had risen a further 3.5 times, from 7.6 to 26.6%. An even higher average annual increase in gas extraction (29.2 billion m^3) must be achieved in the course of the tenth five-year plan period, to exceed the level of the ninth five-year plan period by more than 1.5 times.

It should be noted that the USSR is the only large industrialized country of the world which is able to supply all of its own power requirements, and is able to export large quantities of fuel resources. The stable development of the national power-fuel complex and the improvement of ratios between power engineering and the national economy are the most important national tasks. Supplying the optimal development lines of the

*Translated by V.P. Lysyansskaya.

Table 1: The USSR gas industry development.

Indices / Year	1955	1960	1965	1970	1975	1980 (plan)
Extraction mlrd m^3	8,3	45	128	198	289	435
Average annual increase in extraction over five-year period, mlrd m^3	–	7,3	16,6	14,0	18,2	29,2
Proportion in the national power-fuel balance, per cent	2,4	7,6	15,3	18,3	21,1	26,6

national power-fuel complex for the near future on the basis of economic-mathematical models given in Maksimov (1979a,b) simultaneously determines that Siberia can provide practically all the increase required in the extraction of the principal power resources.

The gas industry plays a special role in developing the Siberian power fuel complex. The rapid rise in Siberian gas output has been possible due to the provision of an increase in industrial reserves of natural gas. An analysis of industrial categories of natural gas reserves in different gas-extracting regions shows that the largest increase in gas and gas-condensed deposits have been made in western Siberia (Maksimov 1979). Table 2 demonstrates the development of the Siberian gas industry over the period 1965–80 (Baybakov 1979).

One may consider 1965 as the beginning of the industrial exploitation of the north of the Tjumen' (oblast') territory, although the amount extracted in that year was insignificant. By the end of the tenth five-year plan period Siberia is expected to provide more than a third of the national gas output, and is likely to maintain a rapid rate of growth.

Table 2. Siberian gas industry development.

Indices \ Years	1965	1970	1975	1980 (plan)
Gas extraction in Siberia, mlrd m^3	0,003	9,3	35,7	155
Proportion in Siberia of the total national extraction, per cent	0,002	4,7	2,4	35,6

Siberian gas is transported up to 3500–4500 km to the European region west of the Urals for domestic consumption and for export. Normal gas pipelines with diameters of 1420-1620 mm would require excessive inputs of metal and investment, so that an acceleration of research and implementation of new pipeline technology is one of the most important national economic challenges. One method which significantly reduces the amount of metal required for pipeline building and improves the technical-economic performance of such long-distance pipelines is to transport the gas in cryogenic gaseous or liquefied forms (Bleykher, *et al.* 1977). Soviet and foreign specialists have frequently attempted to give technical substantiations of optimal fields of employing different schemes for gas transportation by pipeline in large volumes.

The advantages and disadvantages of transporting liquefied gas by pipeline are well known and do not need detailed elaboration. Cryogenic gas pipelines have the advantage that they do not require special and therefore expensive types of steel; the cost of such pipes does not differ considerably from that of normal gas pipelines.

It should be noted that, for the most part, calculations to substantiate the relative costs of different transportation schemes have been based largely on hydraulic and some technical points of view only. Also, the aspects related to different methods of construction of cryogenic and liquefied gas pipelines, as well as economic problems involved in improving reliability have not yet been fully researched.

When the problems of liquefied natural gas (LNG) transportation is analyzed it is reasonable to distinguish between the factors connected with the specific technological scheme itself, and those dependent on the method of pipeline laying used (underground, ground level, or above the surface), in northern conditions. The USSR, the USA, and Canada have gained much experience in the design, construction, and operation of gas pipelines in such conditions, including pipelines where 90% of their length runs through permafrost.

Methods of underground pipeline laying as usually applied both in the USSR and elsewhere are not acceptable in some cases, especially in regions of Siberia, mainly because it is impossible to eliminate the thermal influence of the pipelines on frozen soils in order to prevent subsidence. The formation of heat haloes causes localized thawing, causing subsidence, which is not usually uniform along the length of the pipe, and so results in failure. The use of ground pipe laying (on embankments, half-embankments, and on low piers) usually designed for temperate regions is restricted in order to reduce as far as possible the thermal influence of the pipe on the soil and to ensure a sufficiently stable construction. These measures are necessary because an embankment of significant size would change the surface geometry that in turn will cause thawing of the surrounding frozen soil.

If a gas pipeline is laid on low piers there is also a danger of disruption of the thermal conditions of long frozen soils, but if the pipe is higher than the maximum snow height (about 1.5 m), it will not present a great thermal influence on the soil, thus guaranteeing the most table construction. However, as experience gained in the construction of pipelines in the northern USSR and elsewhere has shown, the cost of laying such pipelines on piers is 2.5 to 3 times that of underground laying.

In this connection, the choice of a rational method of pipeline laying depends on the route chosen, and this is one important factor in improving the reliability of LNG transportation. The length of the LNG pipes from the Siberian deposits through different natural climatic regions may necessitate the use of different methods of laying at different sectors along the route. The choice of any one single method of laying over the whole length of the route is likely to result in a reduction in operational reliability.

For LNG pipeline systems the confirmation of the necessary reserves of gas is essential for forecasting its development and design since, in an emergency any interruption supply to internal and external consumers may have serious consequences both for the power-fuel system and also for the whole country.

As studies in the USSR and elsewhere have shown, the construction and operation of LNG pipes are feasible technically in the very near future. A number of stages in the process of extraction and transportation have already been mastered on a commercial scale, namely:

- liquefying the natural gas extracted from gas and gas-condensed deposits;
- transportation by pipeline;
- achieving a proper level of compression of LNG at pumping stations;
- storing the LNG in reservoirs of different types;
- regasification of LNG at the end of the pipelines and at points of intake en route.

(Bleykher, *et al.* 1977, Corbonell, *et al.* 1967, Duffy and Dainora 1967, Gudkov, *et al.* 1970, Ivantsov, *et al.* 1969, Ivantsov and Livshits 1976, McCarthy 1974, Trudy 1968).

The economic problems of improving the reliability of gas extraction and transportation systems are among the least investigated questions in planning, design, construction, and operation. In investigating these problems significant difficulties are created by unreliable initial data, so that to take this into account in the forecasting and planning stages of complicated systems it is expedient to subdivide the initial data into three groups (Maksimov and Savinykh 1979).

The first group of indices include those for which only range of possible changes are known. For these chance values the available data do not allow any distributions to be determined. The proportion of the first group in the forecasting and planning of LNG systems is insignificant. The major share (60–70%) of initial technical data falls into the third group. When variants of LNG production and transportation differ in the degree of reliability are considered, the variants with a large degree of unreliability are usually characterized by a high uncertainty of initial data. In addition, the realization of variants with greater reliability during a forecast or planning period under consideration is dependent on the degree of the risk.

Any analysis of the economic problems of improving the reliability of LNG production and transportation naturally requires corresponding mathematical apparatus. The Siberian Energy Institute (SEI) of the Siberian Branch of the USSR Academy of Sciences has developed a method of optimal prospective planning for studying large-scale power systems taking into account the reliability of the initial data (Makarov and Melent'yev 1973). This one-level program model is discussed further as an example to simplify the description of the case under consideration. Let the perspective plan for developing and locating a large-scale industrial plant (such as a pipeline network with associated processing installations, together with a set of variants relating to the degree of reliability required) be optimized with the help of a linear program model including n optimizing variables and m constraints (for the sake of simplicity it is supposed that optimizing variables are constrained only by condition of unfreedom: $x_i \geq 0; i = 1, 2, \cdots, n$). Hereafter, unless specifically stipulated, it is assumed that all initial data (coefficient of the objective function, coefficient of the matrix of constraints, and a vector of constraint coordinates) belong to the third group.

Under a set of natural states in works of the SEI, the $(n+1)\times(m+1)$ measured beam is understood (the objective function is not homogeneous), internal and boundary points which correspond to different possible values of the initial data parameters. Under a set of strategies we understand a space of vectors of intensities of optimal system functioning.

States of nature and strategies are connected by specially formed pay matrixes. Naturally the use of any pay matrix may give only a conformity between a finite set of natural states and a finite set of strategies. The choice of a surveyed but representative finite number of natural states out of all $(n+1)(m+1)$ measured beams is the most complicated problem (Maksimov and Savinykh 1979, Makarov and Melent'yev 1973).

Secondly, we should note the direction of the formation and realization of mathematical model the probability structure developed by the Institute of Economics and Organization of Industrial Production (IEOIP) of the USSR Academy of Sciences (Maksimov 1980). When optimization of the prospective plans to develop large economic systems is considered from the traditional points of view, n and m are supposed to be strictly determined. Economic-mathematical models will belong to the class of probability models if the parameters n and m (or both simultaneously) are chance quantities.

Let us consider one of the factors limiting the choice of a parameter n. Let n different transportation technologies applied in a previous planned or forecast period of time be used in the present situation under consideration. All the technical-economic data necessary for these technologies are known to a sufficient degree of accuracy. As to the technology $n+1$ of gas transportation (e.g., some specific LNG transportation scheme characterized by an increased degree of reliability), it is only just working out and we do not know whether it should or should not be employed in that period. In this case, the choice of n, as well as the choice of $n+1$, are not sufficiently equivalent to the real process of the model. The approach in which a number of used technologies is considered as a chance value will be more equivalent (a chance of a parameter n).

When estimating the prospect of developing LNG production and transportation it is most effective to use economic-mathematical models of the probability structure for the solution of such urgent problems as:

(i) the definition of a rational proportion of LNG in the national gas balance;

(ii) to find an expedient degree of increasing the reliability of LNG production and pipeline transportation.

REFERENCES

Baybakov, N.K. O gosudarstvennom plane ekonomicheskogo i sotsial'nogo razvitiya SSSR na 1980 god i o khode vypolneniya gosudarstvennogo plana ekonomicheskogo i sotsial'nogo razvitya SSSR v 1979 godu. M. Politizdat Publishers, 1979, p.39.

Bleykher, E.M., Vladimirov, A.E., Ivantsov, O.M. i dr. Truboprovodnyy transport szhizhennogo prirodnogo gaza. Nauchno-tekhnicheskiy obzor (seriya: Transport i khranenie gaza). M., VNIIEGazprom, 1977, p.63.

Corbonell, E., Guerin, G.G., Solente, P. "Advances in Cryogenic Engineering," 1967, v.12, pp452-454. N.Y., Plenum Press.

Duffy, A.R., Dainora, Y. "Oil and Gas Journal," 1967, v.65, N.19, pp.80-83.

Gudkov, S.F., Benyaminovich, O.A., Odishariya, G.E. Tekhniko-ekonomicheskiy analiz transporta prirodnogo gaza v szhizhennom i okhlazhdennom sostoyanii. M., NIIGas, 1970, p.28.

Ivantsov, O.M., Livshits, L.S., Rozhdestvenskiy, V.V., Sooruzhenie truboprovodov szhizhennogo prirodnogo gaza. M., VNIEEGazprom. 1969, p.36.

Ivantsov, O.GM., Livshits, L.S. Truby dlyz nizkotemperaturnykh gazoprovodov. M. NIPIESUneftegazstroy, 1976, p.25.

Makarov, A.A., Melent'yev, L.A. Metody issledovanya i optimizatsii energeticheskogo khozyaystva. Novosibirsk, "Nauka," 1973, p.274.

Maksimov, Yu.I. Modelirovanie razvitia gasovoy promyshlennosti. Ekonomika i mathematicheskie metody, tom XV, vol. 5, 1979a, pp.978-982.

Maksimov, Yu.I. Modelirovanie razvitya otraslevykh sistem toplivno-energeticheskogo kompleksa. Izvestiya Sibirskogo otdelenya Akademii nauk SSSR, seriya obschchestennykh nauk, vol.2, 1979, pp. 36-40.

Maksimov, Yu.I. Nekotorye napravleniya modelirovaniya vliyaniya sluchaynykh faktorov na razvitie otraslevykh sistem. In: Modelirovanie stokhasticheskikh protsessov razvitia otraslevykh system. Novosibirsk, IE and OIP of Siberian Branch of the USSR Academy of Sciences, 1980, pp.3-23.

Maksimov, Yu.I., Savinykh, V.N. Stokhasticheskie podkhody pri modelirovanii mezhotraslevyhk programmnykh kompleksov. In: Ispol'zovanie ekonomiko-matematicheskikh modeley v tekhnologii planovykh raschetov. IE and OIP of Siberian branch of the USSR Academy of Sciences. Novosibirsk, 1979, pp.29-45.

McCarty, D.A., "Cryogenics," 1974, May, pp.276-280.

Trudy 1 Mezhdunarodnoy knoferentsii po SPY (Chicago, 1968), M., VNIEEGazprom, 1969, vol.16, p.504.

DISCUSSION COMMENTS

CLARENBURG: What does Professor Maksimov expect to be the proportion of natural gas say in 1985 or 1990?

MAKSIMOV: This will grow for a certain length of time and will reach about 30% in the coming years. And after the year 2000 it will become higher.

CLARENBURG: What is the role of public participation in the Soviet Union?

MAKSIMOV: In recent years, the gas industry in the Soviet Union is being developed in unpopulated areas as a stimulant for the development of this area. So the problems you have heard about so far do not exist in the Soviet Union.

CLARENBURG: That is the advantage of having a large country.

CAMPBELL: The sites we have talked about at this meeting have been marine terminals. I take it that you have no marine export or import terminals in the Soviet Union for natural gas or liquid energy gas? In other words, you utilize pipelines and not ships.

MAKSIMOV: This problem is under consideration but at present there are no existing ports.

REIJNDERS: Could your program include choosing between pipeline transport and transport by ship of LEG?

MAKSIMOV: Our model can be used for both cases. In the case of tanker usage, we can consider existing tankers, and tankers which are projected or designed.

REIJNDERS: But could it also be used for a comparison between the compatibility of the two systems?

MAKSIMOV: It is possible. As an example, we transport gas via pipes from the Ukraine in Siberia to the Far East, and there, further transport is provided by tankers.

SINCLAIR: In the figures you gave, were you referring to your total production for internal use or were you referring to the export to western European and other Warsaw Pact countries? How is export dealt with in this model?

MAKSIMOV: Exports are also taken into consideration according to a system of models forecasting the development of the world market.

SINCLAIR: Do you take just one figure for this or do you assume several levels of exports?

MAKSIMOV: We have considered different versions and different scenarios of world market development.

DALL: To the extent that you have thought about exports have you gone further and looked at potential export markets? If you were to build an export terminal on the Pacific in Eastern Russia, where might you put such a terminal? Have you given that any analysis?

MAKSIMOV: They have considered several scenarios of constructing ports on the Pacific. There is a range of possible places starting from the existing ports to construction of a new port. For regions where there is ice cover, the possibility of breaker tankers is being considered.

RAVETZ: Do you generally transmit the gas in liquefied form rather than in cryogenic form?

MAKSIMOV: We speak about this transportation as a perspective technology. There are several pipelines which transport liquefied natural gas.

BARRELL: How long are the longest and shortest pipelines and how many years experience has been accumulated?

MAKSIMOV: They have been in existence for 3-4 years now, and most of them are pilot pipelines, or experimental pipelines. The longest pipeline is 10 km.

SINCLAIR: When you plan for an increase in production in Siberia, are you thinking of increasing production of existing wells by new and better technology or are you including sinking new wells? If you are doing both, what is the proportion of new wells?

MAKSIMOV: Siberia will continue to use the current technology and after 2000, production will be started on the eastern side of Siberia, where places have been explored but so far not utilized. There is a mixture of gas and liquid.

SINCLAIR: Are need projections being reviewed by a five-year plan, or are they continually being made?

MAKSIMOV: They are reviewed on an annual basis because of the discovery of new gas resources.

THE REGULATOR'S VIEW OF TERMINAL SITING

N.G. Campbell
Scottish Development Department

As the issues paper recognises the form of decision taking on development, proposals vary greatly from one country to another. This paper first tries to answer the various questions in the issues paper in the order they are put and as they apply to the United Kingdom. It then considers certain of these issues more generally by way of conclusion. In answering the questions in the issues paper the experience from the procedures leading up to the approval of the natural gas liquids plant and terminal at Moss Morran and Braefoot Bay in Fife has been used by way of illustration. While the illustration and discussion are in terms of the Scottish system, it is much the same as the English system. This project has already been studied by a team from IIASA which visted Scotland earlier this year.

The basic approval required for the siting of a Liquid Energy Gas (LEG) terminal is planning permission under the Town and Country Planning Act. All forms of private development require such approval. The general procedure under the British planning system is for the development control authority tc consult all possible interests on a planning application received by them and then take a decision in the light of all these comments. A planning permission should only be granted if it is reasonable to assume that it can be implemented. This largely avoids the need for the developer to have to collect a number of separate authorisations from different agencies. It simplifies the job of the developer and should avoid a series of contradictory decisions on different aspects of the proposal leaving doubt as to whether it is possible to go ahead or not.

Having said this it may be necessary for developers to obtain separate authorisations in certain cases. For instance with an LEG terminal approval will be needed under the Harbours Act for the construction of any pier costing more than £1m. Approval will also be required under the Coast Protection Sea Act from the Department of Trade and possibly under the Dumping at Sea Act. This however reflects the fact that the Planning Acts apply only to the land and the marine side is the responsibility of separate agencies. There are other exceptions to this general rule. For instance, a separation authorisation is needed for any pipeline more than 10 miles in length if this was part of the terminal proposal.

The object of the British planning system is to decentralise planning decisions as far as possible to the local level. For this reason the development control authority (the one which issues planning permissions) is in almost all cases the basic statutory local authority - the District Council. District Council planning authorities vary in size. The median is 80,000 to 100,000 inhabitants. The smallest are just over 30,000, the largest (a city) is over 700,000. However it is recognised that development planning and development control can raise issues which go beyond the boundaries of the Districts. These issues may have implications over all or part of the Regions which in Scotland form the second tier of local government. Regions have a strategic planning role over areas which are considered to have certain natural or economic boundaries. Their size varies considerably in size from 300,000 to 2,400,000. Development proposals may also raise issues of national importance. For this reason both the Regional authority and the Secretary of State (being responsible for land use planning nationally) have powers to "call-in" an application - that is take it over from the District Council. The call-in power is used very rarely (0.02% of applications are called in by the Secretary of State; 0.2% by Regional Councils). It is considered that in the Scottish system that the balance is in general right between District, Regional, and Central authority although in certain cases there may be differences of opinion between for instance the District and Regional Councils over individual cases.

Taking Moss Morran and Braefoot Bay as an example, the original applications from Shell and Esso were called in by the Secretary of State for Scotland in view of their national importance. However when it came to consider an application from Esso for altering the site of the ethylene cracker which had been approved by the Secretary of State at Moss Morran, it was considered that this did not raise national issues since the Secretary of State had already approved it but that it did raise regional issues since it affected a number of districts. The Regional Council are therefore dealing with it. Another example of the Secretary of State's use of his power to call-in has been the proposal to build an oil production platform site at Drumbuie - a remote and sparsely populated part of the Highlands of Scotland.

The regulator's view of the siting problem will depend first on the area of regulation for which he is responsible. The Health and Safety Executive official will be concerned about safety, the official of the Department of Agriculture will be worried possibly about the loss of good quality agricultural land. National policy considerations can be brought into the equation - for instance, the economic benefits of exporting LEG, or the need to create long term employment. The job of the regulator who takes the decision on the planning application is to take an overall view of all the separate interests and make the best decision which he can in the light of these. Some factors can be balanced against one another - the familiar conflict of amenity versus jobs, for instance. Other factors such as severe risk to human life or severe pollution cannot be balanced against others and have to be regarded as overriding factors in one direction or the other.

This leads on to the third set of questions in the issues paper - the factors taken into account in giving planning approval - and to the not unexpected statement that there is no simple answer to this set of questions. Each case depends on its merits. In practical terms it is usual for one or two determining issues to emerge in any major planning application. For instance when considering an oil refinery in an estuary which is important for wild life the issue of oil pollution and its likelihood and effects will be the determining issue. In the case of a process involving dangerous substances the issue of safety will become the determining one. Clearly in reaching a decision a regulator must attempt to give each factor its appropriate weight. Many of the factors do not lend themselves to quantification and even if they do individually, not to a system of quantification which is comparable across all the factors. Decision taking on major and complex cases therefore involves to a large extent unquantified judgement but a judgement that should have been systematically arrived at by testing each factor and isolating the determining one or ones to sharpen the decision process.

To move on to the fourth set of questions and to concentrate on discussing the full procedures which would be used in a major and complex case. The most important decision is the decision whether or not to approve under the Town and Country Planning Acts and this is only taken at the end of all the procedures which are laid down under the Planning Acts.

Taking the example of Moss Morran the process of application for the planning permission started in January 1977 with the application for the natural gas liquids separation plant. This was followed the next month by an application for an ethylene cracker on the same site and the following month by an application for general petrochemical industrial development on the site. Linked to the first two applications were applications for the necessary jetty for exporting the natural gases (propane and butane) and the ethylene. Each application was advertised as a "bad neighbour" development. This is a technical term which means that the impact of the proposed development is such that it has to be advertised in the Press and notices posted on the site describing what development is proposed. This gives any person and particularly those living round about the opportunity to write in objecting to the proposal.

In view of the national importance of each application all were called in by the Secretary of State for Scotland. The next stage was the holding of a public local inquiry between 27 June and 21 July 1977. Any person who had objected to the proposed development was free to come to the inquiry and both state his own point of view and cross-examine the others giving evidence before the inquiry. Major participants were of course the companies proposing the development and the local authorities. In addition taking part were the Health and Safety Executive giving their opinion on the safety of the plant and the port authority giving their view on the implications for shipping or bringing into their harbour area the extra traffic. The inquiry had before it a full impact assessment of all the likely effects of the development prepared by independent consultants.

Once the inquiry was completed, the Reporter prepared his report of what had been said and what facts had been established at the inquiry. This was circulated to all those who took part in the inquiry so that they could make any necessary corrections. Following that the Reporter completed his report together with his recommendations on whether the application should be refused or not (in this case approval) and submitted this to the Secretary of State. The Report was submitted to the Secretary of State in November 1977. Following the inquiry a new safety issue was raised which had not been considered at the inquiry. This required further investigation by the Health and Safety Executive. Their views and the results of their experimental work were circulated for comment to all those who took part in the inquiry. A final decision to approve was made by the Secretary of State in August 1979.

A public inquiry is usually held by a Reporter who belongs to the independent Reporter's Unit. They are employees of the Secretary of State but their job is to look at each case on its merits and produce independent reports and recommendations. They are helped by specialist assessors where technical questions need to be evaluated.

The form of a public inquiry of this size (and this would go for any controversial proposal) tends to be fairly formal and legalistic. The various parties are represented by senior lawyers accustomed to court work. They introduce their witnesses and cross-question the witnesses of other parties. The local people who objected to the proposed development joined together into a joint action group with their own lawyer and themselves were able to cross-question the witnesses of the developers, the local authority and the Health and Safety Executive. Individuals who were not part of this Action Group also appeared. Some of them made fairly brief statements and did not take a major part in the proceedings but others cross-questioned other witnesses and took a fuller part in the proceedings.

Since there is a single planning decision to be made by one Government Minister at the end of this process there are no overlapping mandates. There is however criticism by developers that the procedures take too long with the implication that they are inefficient. These procedures are regularly looked at to see in what way they can be improved. For instance one improvement which is shortly to be made is to reduce the length of the public inquiry report. It is not considered necessary for all the evidence to be as fully reported as it is at present. Instead Reporters will present what they describe as a case summary not detailing each contribution to the inquiry in the order in which it was given but discussing the issues involved and establishing the facts. This report will still be circulated to parties so that they can say whether this more compressed form of report has got the issues right or not. Procedure meetings and the encouragement of circulation of material in advance are other ways in which procedures are being speeded up without in any way reducing the rights of parties.

The courts do not play any role in the decision process since it is a general principle that the courts are not concerned with the merits of a planning application. There is provision under the Planning Acts for appeal to them if the procedures have not been properly followed. If the courts establish that any party has been prejudiced by failure to observe the proper procedures or by some more general failing which shows a lack of fairness amounting to a failure to observe the principles of natural justice the decision can be quashed. While this may involve the courts hearing much of the background of the case and the issues involved they do in fact confine themselves to the procedural and legal aspects of how the decision has been arrived at. In the case of Moss Morran, the Joint Action Group appealed to the Court of Session against the final decision on a number of grounds although the court did not find in their favour.

The problem is to maintain what is felt to be the right balance between the different interests involved in reaching decisions on major development proposals. This usually means a balance between the developer on one hand and on the other those members of the public who oppose it, although it should be remembered that in many cases there is a substantial body of the public in favour although they do not usually take any prominent part in the proceedings. It is felt that the balance in the British system is about right. It is based on the principles of openness, fairness and impartiality set out in the report of a committee under Lord Franks which reported in 1958. This committee looked at the whole field of administrative tribunals, that is, bodies which although not courts, were taking sometimes important decisions following procedures which had some similarity with a court's procedures. Obviously there are ways in which the balance could be altered. For instance, any objector could have the right to require a public inquiry into any application or into any called in application; there could be appeals to the courts on the merits of a case or the right to a second inquiry if any party was dissatisfied with the results of the first. In practical terms if there is a very large body of objection to a called in proposal there is almost always a public inquiry even although it has not been asked for by either the developer or the planning authority who have the statutory right to ask for it. To give the right to one individual could greatly increase the number of inquiries and delays. To introduce greater rights of appeal against decisions at inquiries would greatly lengthen the process and make it difficult to reach prompt decisions on proposals which may be of economic importance. It is considered that a full public inquiry should bring out all the facts without the need to go over the ground again.

It is considered that the procedure for arriving at planning decisions in the United Kingdom is a fairly open one. Individuals can object and their objections have to be taken into account. When inquiries are held they can take part in them. Where the decision is being made by a local authority the authority may hold an informal hearing and in any case the councillors who sit on the Committee which makes the decision will be made aware of any representations received. Referenda have not formed part of the British planning system. Planning decisions often involve complicated issues which would not readily lend themselves to simplification into questions which could be dealt with by a referendum. There would also be the problem of administering a referendum and knowing whether what would probably be a very low turn out in any vote was truly representative or not.

The main comment of industry on the present planning system is that it holds them up but most realise that it is a necessary process and acceptable so long as it is efficiently carried out without unnecessary delay. The view of local interest groups often depends on whether they feel that the system has produced the answer which they want. Obviously where the right answer from their point of view is not received they will feel that the wrong weight has been put on the various unquantified factors which are bound to come into any planning decision. They may also consider that the system is wrong. Developers often feel the same when they do not get the answer they want.

The areas for discussion on the procedures for arriving at decisions on major projects such as LEG terminals seem to be the following:

1. Information

   All parties--developers, objectors, local authorities--are encouraged to circulate in advance of inquiries written statements of their cases or objections, the documents which they will quote from and written statements of any policies which might be relevant. In general, the fact that an inquiry is being held inevitably means that a lot of information is made public and discussed. Developers have however in any case whether there is to be an inquiry or not been asked to submit full supporting information for major projects. Research has been done in the United Kingdom on the best way in which the impacts of major developments can be examined and presented. The issue of environmental impact assessment as a means of informing the public and the regulator is under discussion by the European

Commission.

The balance to be struck is between too much information being required with an unnecessary burden being placed on developers and ensuring that the planning authority and the public know the effects of what is being proposed. Another problem which sometimes occurs is organising the flow of information so that it can all be brought together at one time and a decision taken. Another issue is ensuring that all those involved whether in favour or against the development are aware of all the information. The procedures for public inquiries are designed to ensure this. Thus the principles on the provision of information seem to be fairly clear that all the relevant information should be available to those concerned about the decision. What is at issue is a question of degree - how much information - and practicality - how is it to be made available and discussed.

2. Speed and Efficiency

It is necessary to remember the needs of the developer to get a reasonably quick and certain decision. Much may be at stake economically. The issues here are designing procedures which are swift but fair and here again the principle is clear and it is a matter of practical design of procedures.

3. Finance

At present all parties taking part in the planning process and in particular at public inquiries where the major expenses are involved, have to bear their own costs. There are limited exceptions to this mainly any person who successfully opposes a compulsory purchase order on his property or any person who suffers from unreasonable action by another party at an inquiry. Some countries have experimented with paying the costs of those objecting to major development proposals. Various groups in Great Britain have suggested some form of Government support for objectors at public inquiries. Were public finance to be available to individuals taking part in the planning process it might well just lead to an increase in the commitment of resources by the other parties leaving their relative positions in financial terms the same and without improving the inquiry process. The solution to this problem seems to lie in ensuring that full information is provided and is freely available to all parties and that developers produce in appropriate cases full statements of the likely affects of their proposed development.

4. National Policy Issues

On occasions difficulties have arisen on how to discuss national policy as it affects major development proposals. This is an issue that arises in relatively few cases. However they are often the most controversial. It has been suggested that the public inquiry and the normal planning process are not the best way in which to discuss national policy issues. For instance they might be discussed at some separate inquiry of forum in more general terms and separate from the siting decision. At present where national policy issues are involved it is possible for representatives of the Government department responsible to appear at inquiries and to explain these policies. The policies themselves cannot however be questioned. The place for doing that is Parliament.

5. Participation

The procedures allow for a large degree of participation in the planning process in Britain. Where there is a large amount of public interest this will often lead to the open discussion of a public inquiry. Major decisions may be taken without an inquiry usually where there has not been a high level of public interest but in doing so this is a recognition that there is not a great demand for public participation in that particular issue.

The general conclusion that I would come to is that the basic principles and framework of the planning decision system in Britain are generally satisfactory although criticised both by developers and objectors for various reasons. Its procedures are regularly under review so that within the basic principles and procedures there is a constant search for ways of making the system more efficient in arriving at decisions and more receptive to public needs.

DISCUSSION COMMENTS

CIERAAD: I doubt that the Scottish system is really an open system; though I am not so familiar with it. From what I understand, once the application for a site has been filed, and the choice is advertised, the interested parties have only three months time in which to prepare their statements. I think that is much too short. This is an example of a public hearing system that is not safe. And it is important, given present technologies to have a "fail-safe" system. A second point on the Scottish procedures is that they have no political checks, at least as far as I can see. Since all the applications have been called in, and I presume that this has been done for reasons of national importance, there must have been features of national importance on these applications. And I presume there were safety issues as well. On a national scale, as well as on the scale that policies are made, there should be the possibility to discuss safety in relation to other issues which may be important. What I missed in the Scottish case is a discussion of the balance among all the different factors that were taken into account.

Mr. Campbell's paper suggests that safety was the determining issue with regard to these projects. I disagree: This is apparently not the case since the projects were approved. I would like to stress that there was a matter of balancing, or of making considerations on a national policy level, which have not been discussed.

Finally, I would like to say something on the quantitative analysis of risk and analysis of other aspects of siting decisions. There are a lot of problems with analyses. I think one should be sure of the facts: everybody should know that analyses themselves can be as subjective as any decision. The meaning of "analysis" is important here. In this meeting it has been a source of confusion since the word "analysis" has been used to mean different things. For instance, it may refer to only "risk analysis," analysis that is intended to quantify some aspect of risk. Analysis can also be performed from the viewpoint of economics. These types of analysis have been rarely discussed here, yet they play a major role. Economic figures seem important and look much more tangible than risk numbers. However, economic figures also have a large amount of uncertainty associated with them. These uncertainties may be relevant with regard to a public decision to go on with a project or not. The risk problem was one of the first issues where both uncertainty of the problem and the life and limb problem were quantified. Economic analyses have not been so controversial since they deal with money instead of lives. But, economic analysis may become as difficult and controversial as risk analysis once uncertainty and the distribution of economic benefits are taken into account.

A third type of analysis is the decision analytic approach, tying together all aspects and coming up with a final number for each alternative. I think it cannot be applied to complex political processes. Decision analysis can be used as long as one group of people, or one single decision maker wants to be identified. If he wants to quantify his decision problem, decision analysis can be used to gain insights. In conclusion, I think we need analyses, but we also need to clarify what analysis can and cannot do.

SINCLAIR: I think you have made two sets of comments, one applying to the studies of systems and the other being more general. We should perhaps separate the two. My feeling, to misunderstand you deliberately, is that the lack of a Parliament in Scottish affairs has been missed for 273 years.

MEHTA: I would like to follow up on the first point that Mr. Cieraad made. The strongest criticism of the Scottish system is not that the people who wish to object to the proposal had something on the order of 3 months or so in which to prepare their case, but that that assessment had been made on the basis of the barest outline of the proposals that were put forth by the companies as part of the planning application. The BBC documentary film on Mossmorran indicated that the companies were reluctant to disclose the engineering details of the project. Hence, it was only possible to do a very superficial assessment on the outlined proposals. I think this is a very important point, especially in comparison with the Netherlands or the U.S., where the proposals are looked at in much greater detail.

Another point is that there was a two-year delay after the inquiry before a decision was made. In those two years the world moved on, science moved on, but the minds in the Scottish Development Office did not. The debate on safety was closed to them and to the Health and Safety Executive who was supposed to be advising them. I find it difficult to reconcile, on the one hand, the assertion that safety was treated as the paramount objective and the refusal, on the other hand, to consider the additional information that came to light after the Public Inquiry. This cast grave doubts on the assumptions that were made at the Public Inquiry. The only exception was the highly esoteric question of radio waves which we had successfully thrown in as a red herring; it had the effect of delaying the decision, but the delay did not help us because nothing else was taken into account.

VINCENT: Speaking from the gas companies' point-of-view, for such a big project of siting an LNG terminal, many thousands hours of continuing work are needed since the starting of the project. That is the reason why, in France, all the subsequent detailed studies, are being worked out during the design period, and consequently, cannot be included in the first files which are to be sent to the regulatory Authorities at the very beginning of the project.

BARRELL: I want to reinforce what Mr. Vincent is saying. The Health and Safety Executive also finds difficulties with the UK planning system in that it is not necessary to reveal very much information when making up an outline or planning application. We, too, suffer from the difficulty of commenting on the safety aspects on the basis of very little material. Like Mr. Vincent, I do not, in fact, think that the material is always there;

despite what has been said by some other people. There really is not much detailed information available at the outline stage. So one is inevitably forced into a situation of trying, if you like, to put things right after the outline planning commission has been granted. Now, in this special case, Mossmorran, it went to a Public Inquiry. Most of our cases involve giving advice on outline planning applications and we are in the same dilemma as the special interest groups of not always having enough information to do a proper assessment.

RAVETZ: It might be relevant to be reminded that the planning system, which is now being used for these very high impact and highly controversial projects, was in fact developed for very routine developments. Neighbors would object usually because their own property would be adversely affected in amenity or in value, or in both. There was quite an admirable system whereby certain persons, certain procedures could get the whole thing settled without a great deal of expense and complaint. That system, which had all the economies designed around small scale, relatively non-technical projects is, again and again, now being unnecessarily used for problems of a totally different character. I feel, if there is any point at which the system can be criticized as unfair, it is from the use of one instrument of government for a totally different problem.

MACGILL: I would like to elaborate on this point. The center piece of this decision was the local Public Inquiry, and there are three classic counts on which the local Public Inquiry system may be considered deficient. One is where national issues take an important part; another is where technical issues take an important part; and the last is where there is an issue of possible alternative sites. The Mossmorran developments raise important issues on all three counts, and the suitability of the Public Inquiry has been brought into question for countless other planning developments in the UK.

I would like to make a couple of other comments. In Mr. Campbell's paper, he says that people are free to present whatever arguments they like to the inquiry. I would question the word "free". It is very expensive; it is time consuming, and it requires some considerable expertise to prepare a convincing case for the Public Inquiry. Local public objectors are necessarily working in their spare time with their own resources. For anyone else appearing at the public inquiry it is part of their paid employment. I would also challenge the use of the word "full" for safety assessment commissioned by the local authorities.

CLARENBURG: The situation of public participation in our country is such that there is a hearing required when the application for a license is submitted as well as at the end of the procedure. There is also the requirement by law for a council meeting. In addition, there is what we call the open public hearing on agenda points, which are also required by law and frequently made use of. Afterwards there are various ways to oppose any decision taken.

My second comment is with respect to the lecture of Mr. Campbell, where he referred to a referendum. Let us suppose the following question for a referendum on LNG was posed: "Would you be in favor of guaranteeing our electricity supply at the expense of a specified site?" I am sure that the majority of the population would be in favor of a guarantee of electricity. Only people living in the immediate surroundings of the site would probably be opposed. How to weigh the interests of the local population is the relevant question, and I do not feel that a referendum on the project resolves this question. It takes the responsibility away from the political level where it belongs.

KUNREUTHER: I want to pick up on the point Jerry Ravetz made that the system as it currently exists is designed for other purposes. Tony Barrell voiced a need for better safety studies, suggesting that the process would be improved if we could demand and get information. Sally Macgill was saying things are not free in this world; it really costs a fair amount of money for us to participate in a process. So we have a lot of different things that are happening. We are starting off with an institution that may not really address the problems that one would be concerned about in LNG. What I was interested in was Barrell's point that you might like to have better information at the very beginning because it would help you in terms of being able to make a better decision. Then Dick Mehta says that the safety goal does not really get the full force that the citizens group would like it to have.

Given these observations I would like to raise the following question: Can the current system be redesigned to respond to above concerns?

MEHTA: This question was in fact addressed by the British Parliament about ten years ago when it recognized that the existing planning system was not appropriate for those problems which either were of national importance or involved difficult scientific and technical questions that could not be debated in an adversarial situation with parties of equal strength. To overcome this limitation, Parliament decided on a system which was called the Planning Inquiry Commission. Instead of a single inspector or reporter you would have a panel of experts, technical people who are experts in the particular field to which the inquiry relates, who would look into the problem for their own sake. They would make a detailed technical inquiry into it to satisfy themselves as to what the technical issues are that need to be addressed and answered. This Inquiry would be done at public expense so that resources would be made available to carry out or do the research which needed to be done. Once the technical questions had been answered, there would be a further and public inquiry where other parties would also have a chance to have their say. Although this improved system is on our statute books, it has never once been used. Having recognized the limitations of the existing system, it is ridiculous that the new procedure has not been used for over 10 years or steps taken to overcome any anticipated objections to the system. The truth is that there is no real intention of allowing any effective public participation in planning. The whole thing is just a token gesture to democracy.

THOMPSON: I think that before we chuck out this British system as being absolutely useless I should report on the day I was at the Windscale inquiry. There was a Swedish television team there filming it, and they were expressing great admiration and interest in this procedure. I have also heard in America many covetous comments about procedures like Windscale. Another example, the Two Lakes Inquiry in Britain was being filmed throughout by an FRG television team. This was something that did not exist in the institutional framework of the FRG, and there was a lot of feeling that it would be very nice to have it.

MEHTA: The Windscale Inquiry was a special inquiry altogether. It was not a normal planning inquiry. It was modeled on this commission that I was referring to earlier.

KUNREUTHER: We are discussing the advantages and disadvantages of a number of different political systems. Whether we can design a better system through synthesizing the merits of several existing procedures appears to be an open question.

RAVETZ: I think what could be quite admirable here is the general British consensual style of government rather than the operation of that particular imperfect instrument. Its almost like the reaction, "your police are wonderful," which in general they are, but this does not mean that the police are beyond criticism.

CAMPBELL: I want to take up on a couple of points. The first concerns the time allowed to prepare statements for public inquiries. This is obviously a question of judgment. For small inquiries it can be much shorter than 3 months, and the question is how much longer do you allow? This is obviously an area for dispute. Each time you have to make a judgment. In the case of Mossmorran during this three month interval, an independent consultant study was carried out at public expense for the project and made available to parties in the inquiry. The final decision in the case of Mossmorran was not made by a politician at the end of the day, that is by the Secretary of State of Scotland. It was not a decision discussed in Parliament because of legal problems, and I am not sure a parliamentary debate would be the easiest way to discuss planning conditions. I honestly do not think you can reach that kind of fairly complicated planning decision in Parliament. Windscale had a parliamentary dimension, which was rather unusual.

Turning to the question of tradeoffs, basically the line of argument for the decision was that the economic grounds balanced the amenity interests. However, the safety factor could not be balanced. We could not say that "this is a big risk but it is going to mean a lot of money." Safety had to be looked at on its own. Only if it could be shown to be acceptable could it have been approved. Written into the decision was the condition that there must be a further examination of the safety of the plant carried out independently and that this has to satisfy the Secretary of State. He will go to the Health and Safety Executive for advice on whether this plant can be operated safely. So there is this second step brought in. In addition, the HSE has certain background powers; for example, their prohibition powers under the Health and Safety at Work Act. Yet, Mr. Ravetz and Mrs. Macgill suggest that the local public inquiry system is "unfair."

I think the three parts to this term "local public inquiry" are worth considering. First, it is local, which is valuable; and since it is held on the site of the proposed development or nearby it, the local people can take part without traveling all over the country. It is public, and it is an inquiry. People can ask questions. Mr. Ravetz said the planning system was developed for small scale developments. I think it was developed for dealing with any type of development in the planning. Obviously it is used a lot on small scale developments, but most single developments do not go as far as a public inquiry. An inquiry is used either in the case of planning appeals (following refusal of permission) and this may truly be for a small development; or it may be used as the means of reaching the main planning decision but only in the largest developments. You would not have a public inquiry into a proposal to put a door or window on your house.

Inquiries are deliberately created for coping with these large things. The inquiry has the capacity for dealing with alternative sites if these are brought in. And it has the capacity of dealing with technical questions by using technical assessors. In the case of Mossmorran, there was a technical assessor to deal with the safety issues.

The local public inquiry system, has proved quite flexible, and has been developed for dealing with quite a range of projects. It is a way of publicly discussing at a place near the proposed site what is involved. And you can bring in, as I say, technical expertise, and you can talk about other sites. To give an example, there were proposals for building oil production platforms at quite a number of different sites on the Clyde. What was done was to carry out a study of these alternatives, which was presented as a document before the inquiries (I think were two) into the platform sites on the Clyde. The alternatives were there for the discussion and formed the background for dealing with the rather odd situation in which you had an excessive number of applications for a small number of sites. This is an example of how it can be used. It has been used in other cases to bring in alternative sites, again, in the oil production platform field in the Northwest of Scotland at Drumbuie.

I do not agree with the statement that the Public Inquiry is a token gesture to democracy. The public takes part in Public Inquiries, and sometimes the public or local interests win, if that was the right way to look at it, and sometimes they do not. The public is free to take part in inquiries, and they, of course, question, and put to the test, the people who are proposing the projects. These points are then taken note of by the reporter who considers them in his recommendations and final decision. I would not agree with the rather off-hand chap in the film who said the Public Inquiry was a political theater. I thought there was something rather theatrical about the way he was making his statement.

SINCLAIR: You have defended the current system well, but Howard asked how can you make it better?

CAMPBELL: The way to make the Inquiry better is to change small parts of it. I know that is not a very exciting conclusion. You could examine the time limit, you could look at the amount of advance preparation, how much in advance, and how extensive it is. It is the degree that we are looking at rather than fundamental changes.

KUNREUTHER: Well, I partly raised the question after I heard Tony Barrell say that we are limited in terms of the kind of information on safety risk that comes across our desk.

BARRELL: If there is not enough information, local planning authorities have powers under the Planning Act to ask an applicant to provide more information. We are considering ways in which we can improve this situation, by unexciting means, but means which may well be effective. One of the problems for HSE is that eight weeks is the total time allowed for planning applications from the day they go in to the day on which the planning authorities are normally required to comment. Given postal delays and general bureaucracy we get 2, 3 or 4 weeks in which to provide an opinion on the average planning application. Not surprisingly, we sometimes do not make it. Then we are criticized for holding up the process.

We do now have an arrangement with some of the major companies that they can come to us, not on the day they file the planning application, but some months in advance when they have some preliminary ideas. We then have discussions with them, so when the formal planning application goes in we are able to provide a somewhat better assessment of the situation then we could otherwise do. So that is one way of improving the system. But it is not in any way a legal requirement. We cannot insist on it. It is a reflection of the British consensus system. It does work quite well with a limited number of companies.

In addition, when planning authorities ask us for advice on an outline planning application we are tougher than we used to be. We often now reply that with the information given to us, we can only provide an incomplete answer. Our incomplete answer in some cases takes the form: "there is sufficient information here for us to be able to say that we think it is *possible* to put a plant on this site without creating offsite risks, but we reserve the right, when we actually see the details of the plant, to judge the plant design to be unsuitable. You will then have to redesign it." And we have actually said something like that on certain occasions. It is not really an ideal situation, from my point of view, and also from the point of view of the companies concerned, that we are obliged to hold back the right to say that the plant is not now safe enough for this site and a new design is what is needed.

CLARENBURG: In the Netherlands, from the day the application for a license is officially submitted, you have a very strict seven months to go through the whole procedure.

SINCLAIR: I would like Mr. Mehta to come back to what Mr. Campbell has said and then Mr. Campbell to respond.

MEHTA: Can I first of all suggest to the delegates here that they read the Appendix to my paper which shows the type of preliminary advice that the Health and Safety Executive are able to give on the really bare information that is available at the outline-planning phase.

I have two points for Mr. Campbell. First, by way of correction, he said that potential sites can be considered at the Local Public Inquiry. That, in fact, is not true. Parties may agree to raise questions of alternative sites, but the whole system is designed merely to look at the planning and technical aspects of a particular site and, of course, has no authority to go beyond recommending whether a particular site is suitable or not. The merit of the Planning Commission, which I mentioned earlier is that it can look at other sites which are not being proposed to see if they are more suitable. A second question I would like to put to Mr. Campbell regards the manner in which additional information, which came to light since the inquiry two years ago, was disregarded. How does that tie up with his assertion of open and fair?

CAMPBELL: Obviously you cannot get permission for an alternative site that is not formally the subject of an application, but you can consider alternative sites, and they can be brought into discussion at Public Inquiries. Concerning your question of the additional information that was submitted after the inquiry, I would quote from the decision letter on Mossmorran: "This information has been submitted to the Secretary of State for his careful consideration. None of these representations, though extensive, raise significant new issues of a kind which were not discussed at the Public Inquiry. Thus, it was not necessary to reopen the inquiry to consider these representations. Parties, however, have been given the opportunity to comment on these representations, and the Secretary of State has taken into account the representations and comments on them." It is thus not the case that they were disregarded. Your view of "regarded" meant opening the inquiry again. That is not the only way that material can be taken into account. The Inquiry is not the norm; and simply because something is not discussed in the Inquiry does not mean it is not being taken into account.

MEHTA: What we are really concerned about is that the Secretary of State ought to have considered the evidence before arriving at a decision. Now we know that the Secretary of State did not take everything into account that was brought to his attention. On every occasion that an additional piece of evidence was submitted to him, his response amounted to a simple acknowledgement. When pressed to say what he was doing with it; how, if at all, it had any effect on the proposals which he was considering, his response, in fact, was a letter signed by yourself. This letter, said that the Secretary of State's decision will be taken purely on the evidence which was considered at the Inquiry with the exception of this highly esoteric question of radio waves.

I would have thought that if the evidence was being considered that the Secretary of State would have obtained advice from respective advisors such as the HSE and would have invited comments from the other parties. The Secretary of State obviously cannot consider evidence without requesting views from the other parties. The only thing he did take into account was the fact that we threatened legal action if evidence was disregarded. A statement was made at that time that no new evidence is being considered except this question of radio waves. When the final decision was made public, the Secretary of State reported, "I have noted everything, and my decision is still the same."

SITING AN L.N.G. FACILITY IN CALIFORNIA: THE REGULATORY FRAMEWORK AND THE FACTORS INVOLVED IN THE DECISION MAKING PROCESS.

By

Randolph William Deutsch
Principal Counsel
California Public Utilities Commission*

A. Introduction

In 1977, the California Legislature passed Senate Bill 1081, the LNG Terminal Siting Act of 1977.1/ This Act essentially created a "one-stop decision making authority" within California state government over LNG facility siting by preempting previously mandated permit requirements in various local and state agencies and vesting sole permitting authority in the California Public Utilities Commission (CPUC). The history of the passage of this Act is itself an interesting study into the dynamics of the interplay among political, bureaucratic, industrial and environmental interests in the energy field in California (and the United States) today, and worthy of a complete and separate discussion. However, within the limits of this paper it must suffice to indicate that the legislature was convinced that the multitude of governmental permits required at the state and local level and the often conflicting responsibilities of these agencies made a reasonable consideration of an LNG facility impossible without a change in the law. In fact the LNG Terminal Siting Act of 1977 starts out with the following, very straightforward, preamble:

> "(a) That an adequate supply of natural gas is essential to the economy of California and to the health and welfare of its residents.
>
> . . .
>
> (c) That an initial liquefied natural gas terminal may currently be needed in order to permit the importation of sufficient natural gas to prevent shortages which have been predicted to occur in the early 1980's.

---

* These comments represent the views of the author and do not reflect an official position of the Public Utilities Commission of the State of California.

1/ Chapter 855, Statutes of 1977; California Public Utilities Code Sections 5550, *et seq*.

(d) That, in order to expedite the siting, construction, and operation of such liquefied natural gas terminal so that serious shortages of natural gas do not occur, it is necessary to vest exclusively in one state agency the authority to issue a single permit authorizing the location, construction, and operation of such terminal, and to establish specific time limits for a decision on applications for such permit."

The passage of the LNG Terminal Siting Act of 1977 set in motion the consideration of the construction of an LNG regasification facility at Little Cojo Bay near Point Conception in Santa Barbara County, California by California State Government. This paper will present an overview of the regulatory process in terms of the structure of regulation under California and United States law, the factors affecting the decision making process and the use of technical analysis in that process.

B. The Regulatory Framework for LNG Facility Siting

The California LNG Terminal Siting Act, of course, only reorganized the regulatory agency review process within California. An applicant for an LNG project still had to obtain federal government authorization. Coincidentally, the federal regulatory process was also modified at the same time as the state process.

Initially (placing this in the time frame of the California LNG projects) an applicant made an application before the Federal Power Commission for authority to import LNG into the United States, for authority to sell the gas to a distribution company, and for authority to construct any facilities used in the transportation of gas that is imported or sold in interstate commerce. The Federal Power Commission assessed the entire project from a review of the gas reserves in the foreign nation to the gas market to be supplied under a legal test of "public convenience and necessity". In terms of scope, this clearly was the most comprehensive review process. The passage of the Department of Energy Reorganization Act of 1977 disolved the Federal Power Commission and created a Department of Energy.2/ Within the Department of Energy, the Federal Energy Regulatory Commission was given the authority over LNG projects involving sales of gas in interstate commerce (Alaska to California) and the Economic Regulatory Administration was given regulatory authority over LNG purchased from foreign countries. The scope of review remained the same as that of the Federal Power Commission. Other federal permits are required such as Coast Guard approval for shipping but these are relatively specialized and involve simple regulatory procedures.

2/ The Department of Energy Organization Act (Pub. L. 95-91, 91 Stat. 567 (1977)).

At the state level in California, permits for the construction of the LNG regasification facility and approval of the purchase of the gas by the California gas distribution companies had been required by the California Coastal Commission, the CPUC and the State Lands Commission.3/ Other specialized permits were required by such agencies as the State Air Resources Board and the State Water Quality Control Board. The LNG Terminal Siting Act consolidated these various responsibilities. At the local level, prior to passage of the LNG Terminal Siting Act, a construction permit was required to construct an LNG regasification facility by the relevant county agencies. The total number of federal, state and local permits required was in the order of 25 to 30. (See Appendix A for a list of these agencies.)

Each level of government focused on a significantly smaller portion of the project of interest to its particular jurisdiction. Whereas the federal agencies reviewed the entire project and were concerned with national energy issues, the state agencies were concerned with the effects of the construction of the regasification facility on the safety of the indigenous population and on the environment and the effect of the price of the gas supply on the state's consumers. The county officials were only concerned with the local effects of facility construction on safety, the environment and the local economy.

Paradoxically, it soon became evident to even the most specialized agency at the lowest level of government that major national issues, outside its level of expertise, had a significant impact on its decision making process. A good example of this is the argument put before county agencies that the facility was not needed because other energy projects would be approved by federal agencies that would make the LNG gas supply unnecessary.

The various levels of government participation in the LNG siting process are a function of the American form of government established as a federal system with a separation of powers between the central government and the states. There is little question that, with certain fundamental constitutional restrictions, the legislative body at each level can preempt the regulatory process of the lower level of government. This was done by the California legislature. A very real ongoing issue in the debate over effective regulation is how much central government preemption there should be.

3/ There was some uncertainty as to which state agencies had jurisdiction and in what areas. The delineation of responsibilities never became necessary because of passage of the California LNG Terminal Siting Act of 1977.

Many political and legal considerations are involved in this issue which override the question of efficiency. The constraints of the size of this paper allow for only a superficial listing of some of them. A problem with the regulation of LNG facility siting is that it involves both energy and the environment. Energy issues respecting the interstate movement of gas have always been within the jurisdiction of federal agencies. However, environmental issues have been considered local in nature. In fact, Congress has established an entire set of federal environmental programs with local officials given the mandate to carry them out.4/ A significant factor, discussed infra, is that the regulatory process is essentially political in nature, so that public participation at the local level can not be treated lightly. Therefore, the problem is one of defining jurisdictions and providing for full public participation in local government decision making without permitting a local jurisdiction to frustrate a national goal or interest. The problem is made more difficult by differing local attitudes toward the subject matter. The population of California is more activist in the areas of energy and the environment than other parts of the country.5/

In the case of the LNG facility application for Point Conception, there have been several attempts made before federal agencies and before federal and state courts to argue that the California LNG Terminal Siting Act is preempted by federal law and is unconstitutional because it frustrates a federal decision. These arguments have so far been unsuccessful.

The Department of Energy chose not to directly face the issue of federal preemption in the Point Conception case nor did the utilities involved. There were several reasons for this. First, any protracted court battle over jurisdiction could conceivably cause the termination of the project. Second, as a practical matter it is doubtful that financial institutions would loan money for the project knowing of the determined opposition of the State

---

4/ See: the National Environmental Policy Act, 42 U.S.C. §4332; Coastal Zone Management Act, 16 U.S.C. §1451; Federal Water Pollution Control Act, 33 U.S.C. §1151; Clean Air Act, 42 U.S.C. §1857; Estuarine Act of 1968, 16 U.S.C. §1221; Deepwater Ports Act of 1974, 33 U.S.C. §1501.

5/ For example, the proposed El Paso Eastern Company, et al. project, FERC Docket Nos. CP77-330, et al., ERA Docket No. 77-006-LNG with a planned LNG terminal at Matagorda Bay near Port O'Connor, Texas received virtually no local opposition although there are several areas of environmental significance near the site.

of California. Finally, it would not have been a politically sensitive decision to preempt California when the state was expressing concerns over safety and the environment. In fact, California's participation in the process did generate a significantly more detailed safety and environmental review than was sought in Washington by the agencies of the Department of Energy.

At present, the issues of government and agency jurisdiction, timeliness of review and public participation in major energy projects are being legislated on a case by case basis. California was forced to pass its LNG Siting Act because of the inability of the bureaucracy to resolve the multitude of regulatory problems. In order to expedite review of a gas pipeline to Alaska, Congress was forced to pass the Alaska Natural Gas Transportation Act of 1977. Legislation is being discussed to approve the building of an oil pipeline from the U.S. West Coast to the U.S. mid-continent. It is possible that this approach to resolving regulatory difficulties will be used for some time to come.

C. History of the LNG Project For California

In the late 1960's, as a decline in traditional supplies of natural gas became evident, Pacific Lighting Corporation, a Los Angeles based gas distribution company, conceived the idea of importing LNG into California. A subsidiary company, Western LNG Terminal Associates, was formed and proceeded with plans to construct three terminals in California at Los Angeles Harbor, at Oxnard in Ventura County, 65 miles from Los Angeles, and at Point Conception in Santa Barbara County, some 120 miles from Los Angeles. The terminals were each to be part of three separate import projects receiving natural gas from Cook Inlet, Alaska, Indonesia and the North Slope of Alaska, respectively. Applications were filed with the Federal Power Commission, predecessor of the Federal Energy Regulatory Commission, in 1973, 1974 and 1975 for the approval of the projects.6/ At the same time, environmental impact reports

---

6/ These applications ran into immediate problems at the federal level because of the form of the applications. Interestingly, the applicant sought to have the construction of each of the three regasification facilities considered in a separate consolidated proceeding. The Federal Power Commission demanded that each facility be considered as part of an overall import project. They were officially denominated Pacific Indonesia LNG Company, Docket Nos. CP74-160, et al., filed on November 30, 1973; Pacific Alaska LNG Company, Docket Nos. CP75-140, et al., filed on November 11, 1974; and El Paso Alaska LNG Company, Docket Nos. CP75-96, et al., filed in September, 1974. As it has turned out, the consideration of the number of LNG regasification facilities in California for the three projects and the location of the facilities has not only reverted back to one combined regulatory hearing, it has taken up the vast majority of the hearing time involved.

It should be added that the complexity of the procedural process and the constantly changing nature of the projects caused significant time delays in the regulatory process and added some confusion and uncertainty to the applications in general.

were being prepared for the local approval authorities such as the counties of Santa Barbara, Ventura and Los Angeles. Applications also had to be prepared for state level agencies.

Before the CPUC ever received an application the original plan to build three terminals was modified to a proposal for one remote facility to serve all the import projects because of changes in the projects themselves and passage of the LNG Terminal Siting Act.

The El Paso Alaska project, planned for the transportation of North Slope, Alaska LNG to California, was rejected by the President's Decision on the Alaska Natural Gas Transportation System which selected a pipeline route for that gas. The Federal Power Commission Staff opposed the Los Angeles Harbor site, to be used to regasify Cook Inlet, Alaska gas, because of an earthquake fault running through the site and because of the population density around the site. Although the Federal Power Commission did actually approve the Oxnard site, to be utilized for Indonesian gas, it did so recognizing that the site did not meet California's remote siting criteria and a modification to the federal application would likely be filed. Subsequently, modifications were made to the various LNG applications so that only one site, Point Conception, was sought for a facility to regasify LNG for the two remaining projects, the Pacific Indonesia LNG project and the Pacific Alaska LNG project.7/

Unfortunately, this maturation of the utility's original plan for the construction of three terminals to the construction of a single remote terminal at Point Conception took a considerable amount of time and effort, and, furthermore, occurred in a manner that lacked overall direction. At times the regulatory review process seemed to be devoid of any sense of reality as, for example, when days were spent reviewing evidence concerning the Los Angeles or Oxnard sites at the same time that both the California legislature and Congress were considering remote siting legislation. Yet there is no means of effectively drawing all government processes together at one time.

7/ An issue, relating to footnote 6, supra, that has remained in the background in these proceedings is whether the siting for a regasification facility could be considered on its own, divorced from any specific import project or even prior to the organization of an import project. This approach definitely has merit from an environmental planning approach. However, it would require a major change in the statutes governing the regulation of such projects. Currently various facets of a project including, but not limited to, the economics, gas supply and demand and shipping are necessary review items in the application proceeding.

Hearings began before the Federal Power Commission, and continued periodically, in the Pacific Indonesia LNG application from December 16, 1975 through February 25, 1977. There were 38 actual days of hearings with 4500 pages of testimony and over 200 exhibits. In the meantime, the Economic Regulatory Administration took jurisdiction over the proceeding. Adopting the record of the Federal Power Commission, the ERA issued decisions on December 30, 1977, September 29, 1978, April 24, 1979 and November 26, 1979 approving the importation of gas from Indonesia to a regasification terminal at Point Conception, California.

In the Pacific Alaska LNG proceeding, initially involving a regasification terminal at Los Angeles Harbor, hearings began on June 1, 1976. However, an amended application was filed with the Federal Power Commission on November 11, 1977 for the Point Conception site. Over 80 days of hearings were held and over 500 exhibits were filed primarily concerning the Point Conception facility. Decisions were issued by the Federal Energy Regulatory Commission (FERC), the agency superceding the Federal Power Commission under the Department of Energy Reorganization Act, approving the sale for resale of Alaskan gas and the Point Conception facility on October 12, 1979 and December 12, 1979.

The CPUC began hearings on the Point Conception site in October 1977 and, after 152 days of hearings, issued a decision on July 31, 1978. All three decisions approved the Point Conception site subject to numerous conditions, the most important of which were the need for further wind and wave and seismic studies.

At the time of writing of this paper, the CPUC wind and wave studies and hearings are complete, the seismic work is complete and a hearing on seismicity is being planned. After the CPUC hearing on seismisity, the FERC will review the seismic evidence. All administrative agencies should complete hearings on the Point Conception site by mid-1981. Opponents of the project will then be able to seek court review in the California Supreme Court (of the CPUC decision) and the United States Court of Appeals (of the ERA and FERC decisions).

D. The Regulatory Environment In the 1980's

The LNG Terminal Act of 1977, at first glance, would seemingly make the CPUC's decision making process relatively simple. The Act not only vests all authority with the CPUC, it sets forth the population density criteria for the site (Section 5582); it requires an on-shore facility (5584); it requires the California Coastal Commission to evaluate potential onshore sites and report to the CPUC by May 31, 1978; it requires the California Energy Commission to evaluate and report to the CPUC on California energy supply and demand. The Act even sets forth the criteria to be taken into account. Section 5031 of the Act requires the CPUC to select a site that is "feasible" to complete construction in sufficient time to prevent significant curtailment of high priority requirements for natural gas. Section 5559 defines "feasible" as taking into account (a) economics, environmental, social, technological, safety and reliability factors; (b) gas supply contracts; (c) gas supply and demand forecasts, (d) federal regulatory requirements and (e) alternative sources of natural gas. The CPUC was required by Section 5580 of the Act to issue a decision by July 31, 1978. The CPUC, finally, is not allowed to issue a permit unless it finds that to do so is consistent with "public health, safety, and welfare" (Section 5632).

Yet, the passage of the Act did not really simplify the decision process for the Commission, although it did resolve the procedural morass that could have embroiled the CPUC in numerous ancillary problems. The Act, in reality, only attempted to give the state, through the CPUC, a relatively effective way of mediating among the conflicting concerns and desires of different interest groups. It is questionable whether the Act, by itself, could serve as a vehicle to resolve the more basic issues surrounding LNG facility siting.

To understand why this is and also to understand the pressures on the decision makers and the elements involved in the process, one must look at the functioning of regulation in the U.S. and the perceptions of various interest groups as to regulation.

To begin, it must be understood that the regulatory process in a traditional "hearing oriented" agency such as the CPUC, or for that matter the FERC, is reactive and adversary in nature. That is, the agency can do little in the siting process until an application is made. The environmental impact review process, so important as an information gathering and issue defining tool, does not come into play until after sites are selected and land is acquired by private applicants. After that, the agency, although it can find alternate sites "more appropriate" can do little more than deny a permit. The utilities select sites, acquire land and do their own studies using their own values. Public participation and agency review begin after the utility has filed its application and essentially made its case. Those adversely affected by the facility as well as the agency reviewing the project are immediately put in the position of being viewed as negative in their orientation, seeking out problems or errors. This regulatory approach is changing somewhat with the creation of newer agencies such as the California Coastal Commission, which attempts to create master plans for such things as energy facility siting development in advance of a specific application. However, this approach is hindered both by the need to know and weigh the specifics of a particular project and the traditional hesitency of private industry to cooperate because of a fear of inviting government into the corporate boardroom.

The adversary nature of the regulatory proceeding creates legal constraints on the agency that further affect how the review process is conducted. Problems of ex parte contacts, confidentiality, rights to due process, rules of evidence as well as strategy-type considerations of a courtroom environment come into play. On the positive side, one can argue that the adversary system used in the United States tests the validity of a siting project application. Any fallacies in the application will soon be brought to light. On the negative side, this approach limits the ability of an agency to either streamline its review process or obtain greater cooperation from the applicant in the earlier planning stages. Certainly a major problem engendered by the reactive and adversary role of the agency is the effect it has on technological analysis. Almost from the beginning, such analysis is colored by legal and political strategy considerations and an "us vs. them" attitude.

Further complicating the analysis of an LNG facility site is the political environment within which regulation must function. Environment, energy and new technologies are three of the most controversial political issues of the 1980's. In the United States, and especially in California, the public has become extremely well educated and activist on these subjects.8/ The "newness" of the LNG technology, at least in the public's mind, meant it was more vulnerable to political attack. The public has also shown a diminishing willingness to rely on the regulatory agency and its staff as the traditional source of expertise on safety, environment, energy needs and overall policy judgments. Certainly, both federal and state legislatures have taken a more active role in overseeing and in some cases superceding agency jurisdictions when they have believed the agency to be unresponsive to issues of concern to the public.9/

8/ It must also be remembered that the issue of LNG siting in California had been debated openly for over two years before an application was made to the CPUC. The fight over the passage of the LNG Terminal Siting Act had solidified various interest groups at an early stage so that normal areas of controversy were accentuated in the CPUC review process.

9/ The CPUC itself was a recipient of this legislative dissatisfaction when the California legislature in 1975 created the California Energy Resources Conservation and Development Commission and gave it certain authority over electric power previously vested in the CPUC.

The application for an LNG regasification facility in California is almost a textbook example of the political nature of the siting process. The hearings before the CPUC brought interventions in the proceedings by established opposition groups such as the Sierra Club, Friends of the Earth and Scenic Shoreline Preservation Committee as well as groups formed specifically as a response to the application including the Santa Barbara Citizens for Environmental Defense and Environmental Coalition of Ventura County. Groups such as the Santa Barbara Indian Center took the opportunity to use the regulatory process to vent long simmering frustrations and claims.

On the other side of the political equation are the industry critics who favored the LNG facility and who complain of regulatory delays, the economic burdens of regulation and the insensitivity of regulators to the needs of business.10/ Labor unions and business organizations testified in the California LNG proceedings in favor of the LNG project in terms of jobs and the economy.

The effects of "politics" and the adversary system on the decision makers and especially on technical analysis in decision making are explored below.

E. The Political Nature of the Decision Making Process

A point that is often misunderstood by members of the scientific community is that regulation is a form of political process. Not only must regulators weigh legal, economic and policy considerations against technological findings, they must "translate" those technological findings into societal values. This task necessarily limits the role of technical expertise in the decision making process and calls for results not always apparent from a review of factual evidence. Additionally, the political nature of the process often dictates how the technical expertise is used. Elizabeth S. Rolph in her book Nuclear Power and the Public Safety, a Study in Regulation analyzes basic obstacles in regulation and measures the adequacy of such regulation when dealing with a field of technology. Ms. Rolph found that there are four primary obstacles in the infusion of technological assessment into the regulatory process. (1) Uncertainty: the consequence of impact of large scale application of the technology on man and the environment is unknown. (2) Distributional Differences: the benefits and burdens of using the technology are

---

10/ The political pressure from industry has evidenced itself in a mood of "deregulation" in Congress as well as a heightened feeling of criticism with the regulatory process. For instance, on August 6, 1980, the Senate passed S.299 directing federal agencies "to fit regulatory and information requirements to the scale of the businesses, organizations and government jurisdictions subject to regulation". The bill orders agencies "to solicit and consider flexible regulatory proposals and to explain the rationale for their actions to assure that such proposals are given serious consideration."

distributed over different populations. (3) Ability To Make Trade-offs: different segments of society attach different values to such things as economic growth, environmental protection and freedom from risk and these various groups are less and less willing to compromise. (4) Political Evaluation: the regulator must make a subjective judgment on such things as the level of safety. For example, while the technologist can determine the probability that harm will occur and the severity of the harm, the regulator must determine the acceptability of the harm by the public.

These obstacles proved to be applicable to the LNG siting process in California and the "political" reaction is quite interesting. From the time of the legislative hearings on the LNG Terminal Siting Act, it became an accepted fact that there were major experimental and theoretical gaps in man's understanding of the characteristics of an LNG spill. This led to a lack of agreement concerning the range of technical analysis required to make an informed siting decision. The CPUC inherited a heated debate on the issue of risk analysis and dispersion modeling which was only partially satisfied by the remote siting criteria in the LNG Terminal Siting Act. The uncertainty of the consequences of the maximum credible accident allows for the inference of countless hypothetical damages from the application of LNG technology which, in a political sense, could not be conclusively determined.

Prior to the CPUC involvement in the siting process, local agencies evaluated risk and made determinations of risk assessment based on other overall goals and perceptions of public reaction in their areas. The Port of Los Angeles, which was business oriented and concerned over economic health at the port, found the safety risks to be acceptable in the Los Angeles harbor and downplayed the risks while emphasizing the increase in jobs, local revenue and energy supply. The city of Oxnard, which was much less enthusiastic about the LNG facility, hired a consulting firm that critiqued the utility's risk assessment model and developed a societal risk or worst case estimate of the consequences of a maximum credible accident at an Oxnard facility. The utility had used a probabilistic determination approach to risk assessment. The societal risk analysis which showed that 50,000 people could be affected by an LNG accident was widely published in the local news media. Using what has been termed as "cascading risk aversion" by William Ahern in his article "California Meets the LNG Terminal", (Coastal Zone Management Journal, Vol. 7, No. 2-34), officials in California began to take an increasingly conservative approach to risk assessment as public pressure increased. The California legislature, taking the position that it was not prepared to choose between differing expert opinions, mandated remote siting in the LNG Terminal Siting Act. The CPUC went a step further in applying that Act by finding that even transient populations on roads or in parks near a site make the risk "unacceptable" at that site. The staff of the FERC, in Washington, and relatively isolated from local public political pressure, developed its own risk assessment model using a probabilistic determination approach from which they found that the risk was acceptable at Oxnard as well as Point Conception.11/

Even with the remote siting mandate in force, opponents of the LNG terminal have continued to argue that "more data is needed" before large scale application of LNG technology can be implemented. Some opponents have taken the approach that the technological assessment of LNG is so uncertain that even the Point Conception site is "unsafe".12/ Other opponents have shifted the argument from safety to system reliability, arguing that the risks of a major accident that would destroy the facility are so unknown that California utilities should not be allowed to rely on this source of gas as a base load system supply. The level of perceived uncertainty of safety has been increased further by a basic public attitude of distrust in the "establishment" whether it be industry or government agencies. The public appears to show a greater willingness to believe that challenges to the utility or agency positions must have some validity. The CPUC has reacted by requiring extensive safety measures at the facility beyond both the remoteness factor and in disregard of any cost-benefit analysis. The other obstacles referenced by Ms. Rolph were made more significant by uncertainties in other areas. The ability to convince the public of the equity of trade-offs between such values as the environment and the economy and safety and the need to distribute the burdens and benefits of the LNG facility among various segments of society has been hindered not only by uncertainty over technological analysis but also by a lack of credibility in the assessment of the need for the gas and a lack of a credible national energy policy.

For the first time, one of the virtually "given" areas of CPUC expertise was attacked. The process by which utilities and the state agency assess energy needs was not accepted as credible by the public. A great deal of criticism was directed at forecasting methodologies. The traditional methodologies were criticized for

---

11/ It is difficult to determine whether a terminal would have actually been built at Oxnard if California agencies had been preempted from the siting process. Clearly there appeared to be developing a ground swell of protest in the area. Soon after the FERC staff analysis, Congress held hearings on liquid energy gas safety leading to passage of the "Pipeline Safety Act of 1979", Public Law 96-129, 93 Stat. 989, 96th Congress. That Act requires the Secretary of Transportation to develop minimum safety standards including remote siting standards for LNG facilities. The intent of Congress clearly was to require remote siting.

12/ The "Citizens for Safe Energy Facilities", a Santa Barbara group, for example, took out a full page ad in the Washington Post of May 8, 1979 arguing that an LNG facility at Point Conception posed a greater threat to Santa Barbara than the Three Mile Island incident did to local communities.

extrapolating from past trends that fail to consider price sensitivity and limit options to traditional sources of energy. Conservation became the champion of opponents to the LNG project. A favorite game has been to play off one energy project against another arguing that the LNG project will not be needed if other sources of supply come to fruition.

Related to the issue of need has been a questioning of the lack of a permanent national energy plan and the federal government's ever changing signals on the priority of LNG in the energy scheme. In an early "national energy plan" the federal government announced, as a guideline, that only 2 trillion cubic feet a year of LNG should be approved for import into the United States. This was subsequently modified so that no specific figure was used. The Economic Regulatory Administration found that the LNG for the Pacific Indonesia LNG project was required in California. However, the Department of Energy again turned around and downplayed LNG. In a speech before the National Association of Petroleum Investment Analysts and the Oil Analysts Group of New York on January 9, 1979, Secretary of Energy Schlesinger indicated that LNG should only serve low priority needs. This policy was reiterated in DOE/ERA Opinion Number Four, "Opinion and Orders on Importation of Liquefied Natural Gas From Algeria" in the case of El Paso Eastern Company, et al., Docket No. 77-006-LNG; and DOE/ERA Opinion Number Three, "Opinion and Order on the Importation of Liquefied Natural Gas From Algeria" in the case of Tenneco Atlantic Pipeline Company, et al., Docket No. 77-010-LNG. In these cases the Department of Energy found LNG to be a marginal supply source.

The lack of national direction on LNG was exacerbated by a seemingly constantly changing direction in overall national energy policy. Questions of whether other supply projects would be approved, whether there would be a limit placed on the importation of Canadian gas, whether synfuels projects would be developed, whether the Powerplant and Industrial Fuel Use Act of 1978 would limit the burning of gas under boilers, and whether alternate fuel would be available were some of the many questions which made an intelligent decision on LNG difficult. Each time there was a significant change in national policy, a party opposing the Point Conception LNG facility would petition for a reopening of the proceedings to analyze the effects on the California project.

In essence, the problems of establishing societal values and tradeoffs and convincing the public to accept the economic and environmental burdens of an LNG project and, more importantly, establishing public faith and confidence that the agency has acted with impartiality and competence, reflecting sensitivity to political values, have been greatly complicated by the above-referenced uncertainties.

Finally, the matter of public participation is important to the regulatory process from both a political and legal standpoint and has an effect on decision making. The CPUC had to be extremely sensitive to the need for public access to the hearings on LNG siting because of the preemption of local agencies. While it is true that a large part of local public testimony adds little to the weighing of more esoteric technical and economic evidence, it does give the Commission a sense of local values and it gives the public a sense of participation in government. Often project mitigation measures can be taken to satisfy local opinion that, although not justified by cost-benefit analyses or technical evidence, is valued in the amount of long term public acceptance of the project.

From a legal standpoint, public participation consonant with the concept of due process is a critical element to the regulatory process. A reviewing court will ensure that every party with a right to be heard is, in fact, heard by the regulatory agency. A problem, of course, is when to cut off an intervenor who is simply causing delay for the sake of delay or who is using the hearing process as a forum for airing general grievances against the entire system. However this can be dealt with relatively easily and is far outweighed by the benefits of bringing the public into the process.

F. The Use of Technical Analysis In Decision Making

In the previous discussion it has been emphasized that the decision on an LNG siting application is political in nature and one in which the use of technical expertise must play a limited role. The decision maker must weigh environmental, economic and public policy issues as well as technical facts. In addition, he must translate those technical facts into political values. Additionally, the final decision might include political considerations not justified by purely evidentiary findings.

The use of technical analysis is further affected by the adversary nature of the siting process. Consultants are rarely hired to "seek out the truth". Their presentation in the hearing room is used to support the position of the advocate who sponsors the consulting analyst. Because of the nature of the proceeding, there develops a "guilt by association" attitude where the credibility of a consultant is impeached if he is put on the witness stand by a client known to have a specific view even if the work is objectively done in a fair manner. Clients often seek out consultants who share their orientation toward specific problems.

In the courtroom atmosphere, expert consultants quickly join in the contest. It is no longer a matter of seeking the truth but of being judged right; of having one's position upheld by the decision maker. Writing in the U.S. Air Force Law Review, Administrative Law Judge Isaac D. Benkin of the Federal Energy Regulatory Commission emphasizes that an experienced judge or lawyer rarely, if ever, cross-examines an expert on the witness stand.13/ The expert will never admit on the record that he is in error and no lawyer should try to illicit such a confession. Quite the opposite, experienced experts soon learn many of the strategic tricks of the courtroom that will allow them to put forth their position more forcefully. Judge Benkin references what he describes as the "hidden ball trick" where an expert will deliberately omit necessary material from his prepared testimony. When the expert is cross-examined on this point by the opposing counsel the expert then uses the opportunity on the stand to highlight and strengthen his position by lecturing on the omitted material.

The inability to adequately critique opposing expert analyses in the courtroom setting has lead to the use, by various parties in a disputed proceeding, of a number of experts in a repetitive fashion to bolster their case.

This is not to indicate that there is a belief that experts cannot be trusted or that technical analyses are disregarded. Certainly it is not the analyst who has created the system in which he is being asked to work. Nevertheless, all of the above factors have an effect on the regulator. The regulator is often faced, as in the LNG case, with conflicting analytical conclusions presented in a manner that supports the views of opposing parties. In a controversial proceeding he is faced with a multitude of studies on various subjects all leading to the question of whether a facility should be built. Moreover, the regulator is concerned with weighing broad policy issues and probably does not have the time or expertise to weigh the nuances of various studies.

Therefore, one finds a tendency to take a "bottom line" approach to studies. What are the gross conclusions? Taking this one step further, the regulator often finds that studies will "cluster" around basic positions, differing more in technical degrees than ultimate conclusions. Therefore, in order for a particular study to come to the regulator's attention and significantly affect a proceeding it must dramatically raise an issue that reflects compelling evidence that the benefits of the project are outweighed by risks displayed in the problem raised.

The above thesis was clearly shown in the California LNG siting proceedings. At an early stage in the proceedings, various parties

---

13/ "Is It Bigger Than a Breadbox? - An Administrative Law Judge Looks at Cross-Examination of Experts" (U.S. Air Force Law Review, Volume 21, No. 2 (1979)) sponsored risk assessment analyses, each of which differed in methodology and conclusion. The decision makers in the state did not feel qualified to decide whether the risk was 1×10^{-6} or 1×10^{-7} or whether a probabilistic analysis approach or a worst-case deterministic approach was appropriate. They understood that there is risk involved; there is no real agreement on the measurement of the risk; and there are gaps in the basic understanding of the risks involved in the technology. Therefore, the decision makers decreed a policy of remote siting.

Well into the LNG proceeding on the Point Conception site a geologist retained by a party opposed to construction of the LNG facility testified that he had found, what was in his opinion, an earthquake fault running through the site that conceivably had the potential of precluding the construction of any high technology industrial facility at that location. This immediately stopped the LNG proceeding dead in its tracks and generated the seismic studies referenced previously. Obviously, if the geologist was correct any compensation for this risk, if indeed there could be mitigating measures taken, would be so costly as to outweigh the benefits of the project.

The regulatory agency can, of course, hire its own technical consultants to review a project. In fact, the CPUC made extensive use of such consultants. (See Appendix B of this paper.) This gives the regulator more faith in the objectivity of the analysis but it does not modify the basic tendency of the decision maker to look for gross conclusions that can be weighed within the broad policy decisions that must be made.

Why then does the regulatory agency bother to use expert analyses at all? There appear to be three general conclusions, at least in the case of LNG facility siting.

(1) There is an acknowledgement that there is risk or uncertainty in the technology. One needs all the information one can obtain. It is worthwhile even to ascertain the level of uncertainty or disagreement in the scientific community. The regulator can get a sense of the general focus or tenor of expert conclusions. Basically the more information the better even if it is imperfect. (There are two caveats to this latter statement, however. First, the regulator must understand the limits of the information he is getting and that it will not be definitive or dispositive on the issue. Second, he must be able to determine when the "need" for more studies is outweighed by the costs of delaying the decision on the project further. A common argument in an LNG siting case is that "more study needs to be done".)

(2) Occasionally, as in the case of the earthquake fault report at Point Conception, a study will raise a truly key element

on which the application proceeding could turn, that had previously been unknown to either the applicant or the regulatory agency.

(3) Studies by experts give the decision maker credibility. He has something concrete to rely on and refer to in his decision. It will certainly add public confidence in his opinion if he can explain what he found compelling in various technical studies.

It must be added that technical analyses are probably used in greater detail, not in the making of the ultimate decision on the project, but in establishing the mitigating measures that the regulator will require for the project.

Finally, it should be pointed out that although a great deal of information in an esoteric area such as risk analysis might be underutilized, it appears that the more technical type studies are, in fact, the most helpful to the regulator. The decisional analysis or cost-benefit analysis has not proved to be an effective aid in the decisional process. The basic purpose of the cost-benefit analysis is to present costs and benefits in a systematic or quantified form so that a rational choice among alternatives can be made.14/ However, the determination of the best alternative must include the full spectrum of social, economic, environmental, and political values and reducing an analysis to a ratio or dollar amount can obscure the larger social, economic and environmental goals that bear equal weight in the decision process. More importantly, the regulator understands the political process and the social forces bringing pressure to bear on the particular decision he must make. In most cases he is more qualified than the outside consultant to set forth and weigh these matters. In fact, it might be counter-productive to attempt to quantify various political values involving the environment, energy, cultural resources and the economy.

G. Improving the Process

The regulatory process for dealing with an application for the construction of an LNG facility is complicated by the fact that the issues cross the line between energy and the environment. These areas are normally reviewed by separate agencies and indeed separate levels of government. There can be little doubt, however, that the system must be improved for the benefit of all concerned.

14/ See: Cost-Benefit Analysis: A Handbook, by Peter G. Sassone and William Schaeffer (1978); Benefit-Cost Analysis: A Practical Guide, by Lee G. Anderson and Russell F. Settle (1977).

There must be, first of all, a delineation of responsibility among levels of government and among agencies. Although there has been a history of confusion and dispute on this subject, the various lines of responsibility are not difficult to draw. The federal government must establish a national energy plan that sets forth the function of LNG in the scheme of priorities. The federal agencies are best able to make determinations on such matters as the security of foreign sources of supply and ship charter contracts or ship safety. The federal government must make generic rules for LNG safety and must sponsor the necessary long term technological studies in such areas as plume dispersion modeling. However, there is a need and room for local government participation in the siting process both as a participant in federal proceedings and as an arbitor of local issues. Environmental issues have been recognized as a local concern and as long as the state government does not completely frustrate the federal decision it should be allowed to make environmental decisions. Other local decisions that could be made include rate design for the purchased gas and added safety and environmental measures for the facility. All of these matters add to the very important need for public acceptance of the regulatory decisions.

There is also an agreement on the need to streamline the decision process. Efforts have already begun in this area. The President's Council on Environmental Quality has proposed new regulations that would standardize environmental impact reports and limit their volume as well as setting stricter time limits on the preparation of the reports and establishing rules for federal inter-agency cooperation. (See: 40 Code of Federal Regulations Parts 1500-1508). The State of California has made similar efforts under the California Environmental Quality Act. (See: California Public Resources Code §§21000, et seq., and in particular §21100.2, "establishment of time limits".)

Serious questions still remain concerning how to obtain better government-industry cooperation early in the siting decision process and how to effectively obtain public participation in and public acceptance of the regulatory decision. In the long run it serves no valid purpose to have a project terminated by delay or frivolous appeals generated by public mistrust or misunderstanding.

There is, additionally, a need to make better utilization of technical consultants in the regulatory process. For the regulatory agency this can come primarily from experience in dealing with consultants. The agency must have sufficient staff expertise to articulate what is needed in a study and to generate satisfactory interaction with the consultant as the study progresses. There must be a "meeting of the minds" and an ability to change direction at any time as new information is developed. Flexibility and a clear knowledge of the objective to be obtained are too often missing.

It is not uncommon for an agency, inexperienced in the use of outside expertise, to hire "a big name" to do the most expensive study possible just for the sake of having the study.

From the consultant's point of view, there needs to be a better understanding of the political nature of the decision making process and the adversary nature of the regulatory hearing.

A consultant must make every effort to remain objective and not be drawn into the adversary process. A client expects the expert to be honest about what he knows and what he doesn't know. The client must be told, for example, how far the expert can extrapolate from his methodology or fundamental knowledge. It is often tempting to try to satisfy a client who, in the heat of battle, seeks conclusive answers to unaswerable questions. The consultant must clearly set forth the assumptions and methodologies used. He should make sure the client understands if there are other valid methodologies available. In an adversary proceeding such things assume importance often beyond what they should. Most importantly, the expert must be satisfied that he understands what is being asked of him. Often the client doesn't properly understand what he wants. It serves little purpose just to spend the client's money and conclude that "more work needs to be done". Not only does the task need to be clearly defined but the format of the results must be determined. In an arena where the regulator must make the ultimate political decision there is room for a variety of forms of conclusions in a report.15/ The CPUC has, for example, asked experts to simply list all of the elements or factors in a field of expertise relating to the LNG site and it has also asked experts to give conclusions that very nearly reach the ultimate question of whether a facility can be built. Technical analysis is best utilized when all parties involved understand the limits of the expertise available and the proper function of the analysis in the political decision making process of the regulatory agency.

15/ The problems that can develop in this area were exemplified by the natural gas supply and demand study done by the California Energy Commission for the CPUC under the directive of the LNG Terminal Siting Act of 1977. The California Energy Commission carefully constructed a number of possible supply-demand scenarios for California. Unfortunately, the CPUC was expecting an expert recommendation on "the time when significant curtailment of high priority requirements for natural gas are likely to occur." The CPUC sought a specific recommendation and the California Energy Commission presented all the possible scenarios with no conclusion offered. This lack of a meeting of the minds on the goals of the study greatly reduced the value of that study to the LNG siting decision. (See Transcript Volume 44, pages 4514-4517, CPUC Case No. 10342, April 12, 1978 for a discussion of this between the Administrative Law Judge and the sponsoring witness of the subject study.)

APPENDIX A

SAMPLE LIST OF REGULATORY APPROVALS REQUIRED PRIOR TO PASSAGE OF THE CALIFORNIA LNG TERMINAL SITING ACT

FEDERAL

Federal Power Commission	Issue Certificate of Public Convenience and Necessity
Environmental Protection Agency	Approve Environmental Impact Statement
Corps of Engineers	Permits to construct pier and breakwater
Federal Aviation Administration	Determine that facilities not hazard to air navigation
Coast Guard	Approval of procedures for ship handling and cargo transfer
Occupational Safety and Health Administration	Approval of facility construction and operation for worker safety rules
Commanding Officer, U.S. Naval Base, Long Beach	Determine that marine facilities do not interfere with military operations

STATE

California Public Utilities Commission	Approve rates and facility financing
California Coastal Commission	Permit for plant siting and construction
California Regional Water Quality Control Board	Discharge Permits for dredging, construction dewatering, hydrostatic testing
Division of Industrial Safety	Worker safety permits
Division of Highways	Roadway arrangements
Harbor District	Approval of fire and safety equipment
Air Pollution Control District	Air emissions permit
State Land Commission	Lease to cross state tide lands

County*

Los Angeles County Air Pollution Control District	Construction and operating permits
Los Angeles County Flood Control District	Storm and Flood control measures

---

* This represents the Los Angeles project. Each county would have its own separate agencies.

APPENDIX A (Continued)

County (Continued)

Los Angeles County Building and Safety Division	Building permits
Los Angeles County Planning Department	Zoning changes

City*

Building and Safety Department	Building permit
City Planning Department	Use permit
City Fire Department	Fire and safety protection equipment approval
Harbor Department	General permit

---

* This represents the Los Angeles project. Each city would have its own separate agencies.

APPENDIX B

LIST OF OUTSIDE CONSULTANT STUDIES USED BY THE CPUC

1. Studies Utilized for the Environmental Impact Report

   Geology and Seismic Analysis
   Draft Vessel Traffic Analysis
   Meteorology/Air Quality Analysis
   Marine Biology
   Terrestial Biology
   California Natural Gas Supply and Demand
   Missile Hazards Analysis
   Decision Analysis of California LNG Siting
   LNG Vaporizer Seawater System
   Alternate Site Analysis
   Consequences of LNG Spills
   Berth Availability
   LNG Reliability Study
   Cryo-utilization of Cold Power
   Energy Use Study
   Utilities & Effluents Study
   Noise Assessment
   Socioeconomic Land Use
   LNG Safety Study Analysis
   Cultural Resources
   Evaluation of Seismic Criteria and Design Concepts
   Sabotage Analysis

2. Post Environmental Impact Report Studies

   Air Pollutant Emissions Inventory
   Seawater Intake Systems
   Terrestial Biological Appraisals for the Electric Transmission Line and Access Road
   Cultural Resource Appraisal of Transmission Line and Access Road
   Geological Advisor to CPUC to evaluate seismic studies
   Structural Advisor to CPUC to evaluate seismic studies
   Cultural Resource Manager to CPUC

DISCUSSION COMMENTS

KEENEY: I would like to make a couple of points from an analyst's point of view. A lot of what you said analysts would agree with. I certainly think that anybody who does sensible analysis recognizes that any procedure can be misused. Another point you made several times is that values and uncertainties are important: "You, as the regulator, must make the decision." In fact, you must decide if it is safe enough and deal with the value tradeoffs. I would suggest that analysis might help you make those value tradeoffs. The third point about the analyst being his or her own worst critic is sometimes true. In any power game, a group likes to be in control. As a profession, the lawyers have been tremendously good at this. Analysts as a group, although not as organized as lawyers, are a potential competitor for some of the things lawyers have controlled in the U.S. for years and years.

DEUTSCH: I really cannot talk to the last point. It is an interesting thought that I have not considered. In my mind the next question you have to decide when you hear us talking about societal values and irrational decisions is "how are you going to effectively use these tools you are developing? Will you try to use them for every decision or will you decide when they start becoming less effective in benefit/cost terms?" A problem I found with analysis in the courtroom is that the analyst is pressured by the lawyers and, hence, sometimes makes statements that cannot be defended by his methodology. This gets himself and his client into trouble. The analyst should find out first what the real world is like and then make an honest decision on where he thinks his analysis can be useful in the decision making process. I do not think it can be of use all the way across the board to decide all the societal issues in the siting process.

DALL: I do not agree with your comment that players in California oppose LNG facilities because they want to go to the soft energy path. I think the California LNG critics agree that natural gas is a desirable fuel because of its beneficial air quality effects. Our criticism of LNG in large part hinges on the expensive technology associated with it, the economic risk to the end users, if you will. An economic analysis of LNG, if comprehensive, will suggest alternatives. For instance, the $2 million of the California budget required to review the Point Conception application could have paid for 500,000+ residential solar water heating systems in-lieu of gas-fired water heaters.

DEUTSCH: You make a very valid point. What I was saying is that there are some people who have a specific ideology—to stop utilities building new plants simply because they want to take power away from a large utility. That is their reason for objecting to the facility.

THOMPSON: I think it might be worth pointing out that it was not our intention to give you an easy time. There are many parties to the decision process who are not represented here at this meeting. The Sierra Club, as a "civilized intervenor," is like a non-conformist church, but you see sect-like "uncivilized intervenors," such as the Friends of the Earth, who break off with their charismatic leader. These groups are much more uncompromising. We are having such a cozy meeting because all the uncivilized intervenors are not here. We are still a long way removed from the real world.

DEUTSCH: I agree with you completely. But I think you see it even more with nuclear than LNG. With respect to the Californian Diablo Canyon plant, I heard people say to me "It will never be operated." And they meant it. They are going to go and chain themselves to the front building gate. I do not know how the government is going to deal with this type of reaction. You are exactly right. It brings me back to my point that the real world out there is a lot different than what we are seeing here. And I do not know how you can get those emotional reactions into the analytical process.

LATHROP: I want to follow up on that. Are you saying that analysis has no hope in that contentious environment? I think Ralph Keeney would say that analysis would help in the more compromising parts of the process, but do you think that analysis could be used with the commissioners themselves in a way that helps them to defend their judgments, even in the face of less compromising people?

DEUTSCH: Yes, that is the point that I was trying to get at. The analyst, or someone in authority, has to decide the limits of these analyses. You reach a point where you can figure out the more rational and compromising types of things with analysis, and then you use sheer political force to see who will offer you the path of least resistance. I am not so sure analysis can help you with that latter part of the decision process.

CLARENBURG: Although Deutsch's paper is excellent and describes very well the situation in California, I had a very emotional reaction. It was an account of how to wreck a country: how many days of hearings?; how many pages on non-read documents are produced?; how do you synthesize those things? This was defended by Mr. Deutsch; and in the U.S. context, it serves a purpose. But as pointed out by Mr. Vincent, the European approach must be otherwise. We are living in a much more competitive society. When you go a 100 miles north, south, east, or west, from Holland, you are either in Germany, Belgium, France, or England. And if we take 50 years of planning to come to a decision on any project the companies will settle in these other countries. In addition, in our country, which is very densely populated, there is no place under the sun for a remote site.

Briefly reviewing our process, for any project which requires environmental licenses, we are required by law to consult with the company and to submit the plan to the authorities. In the present case of the LNG terminal, we were required to make a study taking into account the importance of the project for the regional economy, the impact on the regional plan, and, of course, the risks involved for the population. We studied six alternative locations, or combination of locations for bringing the LPG onshore and transporting it to the user by vessel, train, or car, including concentration and subsequent transportation of LPG to the user by pipe. The economic analysis brought forward that, contrary to LNG, LPG was essential for our industry. The risk analysis showed, surprisingly, that there was no real difference in the overall risk level among the six alternatives studied. It turned out that the site of the terminal itself did not add even a decimal point to the overall risk, which in most of the studies was entirely determined by transportation to the terminal and subsequent transportation to the user. The points I would like to make are that (1) risk analysis is a very useful tool in finding the weak spots in a chain (relative analysis), (2) the site alone is insufficient to study, you must study the entire chain, and (3) the approval of the project must be based on political decision, where the advantages of the project are weighed against the risks.

A major problem that we now are facing is how to weigh the voice of a small population against the total population when you are talking about projects of a national interest, the problem of equity. At what level should decisions in such cases be taken--at the municipal level which has to take into account all the interests of their own population, on the provincial level, or on the national level? That is the question which remains in my mind and which I have not solved.

SINCLAIR: I think that is a question we have come across ourselves in our own analyses.

J. SCHWARZ: I am not sure I agree with Mr. Clarenburg's point that the LPG terminal did not, even marginally, increase the risk level to the local population.

CLARENBURG: In the predecision phase many consultant bureaus from all over the world took part in the risk assessment of various parts of the chain. From this work it appeared that the risk for the population in our specific situation is entirely determined by the transportation of LPG by ship to and from the terminal. When after public hearings doubt was cast as to the validity of the risk analysis, a counter-expertise was asked from TNO, an organization not involved in the decision making process up to that point.

J. SCHWARZ: But TNO was involved in another process, the making of their Yellow Book, and Rijnmond was connected with this process also. The other consultants you have had were all involved in very specific problems connected with the total technical designs of the siting. I think if you want to reach a decision that is credible and acceptable to the public, you must take a contract with a consultant that does not agree with you, or at least uses mathematical methods which are not similar to your methods.

THE ROLE OF TECHNICAL ANALYSES IN CALIFORNIA ENERGY FACILITY SITING DECISIONS

William R. Ahern
California Coastal Commission

Sometimes technical analysis makes a major contribution to a decision on a major energy facility, and sometimes it does not. An Exxon Corporation lawyer told me about obtaining permits from the U.S. Army Corps of Engineers. The permits were needed to lay oil and gas pipelines through the swamps and marshes of Louisiana. Exxon would apply to the Corps for a permit. Then all the fishermen in the area would send in an objection to the application. The Corps permit analyst would tell Exxon to "work it out." Exxon would then pay each fisherman $10 or $20, the fishermen would remove their objections, and the Corps would grant the pipeline permit. Not much of a role for technical analysis - only, how much to pay?

On the other hand, the Administrator of the Economic Regulatory Administration of the Department of Energy had a huge analytical apparatus to serve his decision approving a liquefied natural gas (LNG) terminal at Oxnard, California. Both the gas company applicant and the Energy Department staff deployed large computer models to show that the risk to public safety from the terminal would be at acceptable levels compared to other safety risks. Many days of public hearings before an administrative law judge were held on all major issues. Experts testified at these hearings on the need for the gas, the reasonableness of the cost of the gas, and the role the gas would play in the California and national energy supply pictures. The major participants cross-examined each others' experts, and the judge submitted a large reasoned recommendation to the Administrator based on the hearing record. The Department staff prepared a large environmental impact statement, which analyzed all the potential impacts of the project with the help of consultants and experts. The analysis compared alternative sites for the project with respect to a number of attributes, including cost, public safety, and environmental impacts. The Administrator made his decision approving the project, with a large number of conditions, in Washington, DC. A wide variety of technical analyses appeared to have played a major role in the decision.

This paper presents a few reflections on the role of technical analyses in such decisions. It then discusses some energy facility siting cases and their outcomes, ending with a few recommendations on how to improve the role of technical analysis.

REFLECTIONS

Technical analysis generally seems to have a subsidiary role in California energy facility decisionmaking because we are still a pluralistic democracy that goes out of its way to protect minorities from the potential "tyranny of the majority." There is a strong sense that nobody should be harmed by the approval of an energy project, even when the project has clear broad benefits to society as a whole. Many interests, particularly environmental protection interests, are now represented by single purpose agencies which can minimize or prevent harm to their goals. But where there is remaining harm, particularly to a local area which has to accept a new risk, we have no mechanism for compensating them such as Exxon's ability to give out money. Our decisionmakers have a stronger sense of equity then efficiency, seem to care more about the distribution of costs and benefits than the overall level by which benefits may outweigh costs. Thus decisionmakers, not surprisingly, like to see the major problems "worked out" by the applicant. This generalization may apply both to highly developed areas, such as California, with its educated and vocal interest groups, and to underdeveloped areas with their informal consensus decisionmaking. Obviously this generalization did not apply during the industrial revolution.

Technical analysis also seems to have a subsidiary role because ideology seems to play such a large role. Ideology is a body of doctrine and myth applied with reference to some political and cultural plan. Very broad ideologies are, of course, capitalism, communism, Islam and asceticism. Ideologies in California that come into play in energy facility siting include: "corporate owned large scale energy facilities are the most economically efficient way to provide energy;" "dispersed small scale labor intensive energy facilities are most desirable to create jobs and preserve the environment;" and "energy facilities should use only renewable sources such as the sun and wind." Decisionmakers, agency staffs, applicants, the press, those with influence on the decisionmakers, and interested parties generally reflect long held ideologies such as pro- or anti-business, strong moral concern for the environment, or cost-effective approaches to environmental protection, pro- or anti-nuclear power and all that implies, pro-capital intensiveness or pro-jobs, and so forth. Ideologies affect how people look at the results of analyses. They affect, of course, the questions that are asked about a project, and they generally result in preconceived notions about a proposed energy project which cannot be changed by analyses.

The professions also affect preconceived notions. Decisionmakers, agency staff, and applicants can reflect the outlooks of professions. An engineer will generally approach a public safety risk as something that can be minimized through sound engineering practice. A biologist, on the other hand, looks at "hard" technology and public safety risks as inappropriate human intrusions on natural systems. An economist may provide a cost-efficiency look, while a lawyer may worry about legalities and groups that might sue. The California Public Utilities Commission staff is primarily engineers, while that of the California Department of Fish and Game is primarily wildlife biologists. The staffs and their recommendations can be quite different on the same issue.

Analysis also seems to play a small role because the major energy facility siting decisions are political rather than technical decisions. The major interest on the part of decisionmakers is still - who is for it?, and, who is against it? This applies mainly to individual projects. There seems to be much more analysis when general groundrules are being developed. The development of federal regulations on nuclear power plant siting or LNG terminals or pipeline safety involves more dispassionate staff analysis, because it is not associated with a particular project, and involves more analytical participation of interest groups and industry. They generally retain experts to affect the regulations. There can be broad participation by ideological groups, from the industry association to the Natural Resources Defense Council. On decisions where there are fairly clear standards and regulations, analysis plays a strong role because the technical question is, does the project meet the standard or regulation? But where the decisionmaking is more *ad hoc* and discretionary, the role of analysis seems much less compared to that of ideology and distributional considerations.

Let us next look at some cases, in which I draw conclusions about the role of analysis and the major factors affecting the decisions. The role of technical analysis will depend on the type of project, the character of the decisionmakers, the issues involved, access to the decisionmakers by other parties, shared ideologies, the professions involved, the quality and credibility of analysis, who has the "burden of proof", the extent of uncertainties, and many other factors.

CASES

The LNG Terminal. The proposal to build California's first liquefied natural gas (LNG) terminal has resulted in spending many millions of dollars for technical analyses. The analyses focused on three issues: the risk to public safety, the need for the LNG and its role in California's energy supply, and the "best" site for the terminal.

The safety analysis was overwhelmed by what I call "cascading risk aversion." The gas company employed Science Applications Inc., which developed a million dollar computer model that showed the risk of a death per year was about 10^{-9} and that such a level of risk for an individual is less than the risk of being killed by lightning. The Department of Energy staff also did a model, with similar results. Because that staff used a yardstick that an acceptable risk was 10^{-7}, they found the risk acceptable. The decisionmaker, the Administrator of the Economic Regulatory Administration in Washington DC, far from the proposed site in the City of Oxnard, agreed. The State decision was another story.

The LNG terminal would also need many permits from local and State agencies. The gas company applicant realized that the project would be delayed or prevented by at least one and probably more of these permit requirements. So it developed a political campaign to place terminal approval authority in the hands of one congenial State agency, the Public Utilities Commission (PUC), which was known to favor the Oxnard site. Business and labor joined together, the Governor favored the project, and environmentalists were neutralized by special provisions in the legislation. However, all the risk analysis that had been conducted, scary press stories, and the outcries of Oxnard area people persuaded the California legislature to be highly risk averse. It reached the opposite conclusion from that of the federal administrator. The resulting Act declared that the risks of LNG were unknown, and therefore the terminal had to be in a remote area of the coast. This eliminated the Oxnard site.

With respect to safety risk, what essentially happened was that "worst case" analysis, the worst number of people who might be killed, drove out "expected case" risk analysis, which estimated the average probabilities of any one person being killed. The "worst case" led the Legislature to require the terminal to be sited far from populated areas. There were uncertainties about the probability of an LNG spill accident, the distance a gas cloud might travel, and the chances of the cloud's being ignited. The remote siting requirement increased the expected cost of the LNG terminal by at least $350 million and made it much more difficult to find an acceptable site.

There was also much analysis forecasting gas supply and demand. There was even a formal decision analysis done by Applied Decision Analysis. There were many uncertainties about the availability of different future sources of gas, such as Alaskan gas or gas from coal, and about future gas demand. The Public Utilities Commission engineers essentially did a deterministic forecast making their implicit assumptions about which sources of gas would actually come forward in the next twenty years. The Energy Commission with its econometricians used an econometric model, with all the assumptions about future economic variables that such a model uses, and Applied Decision Analysis, as consultants to the PUC, developed subjective probability estimates for presenting the probabilities and risks that other gas supply sources would actually occur.

None of these analyses showed a clear and unimpeachable need for the LNG, nor did they show it was not needed. The decision analysis explicitly treated the risks and uncertainties, but its conclusion was that the project did not have great expected benefits, nor did it have great expected net costs. The decision analysis was basically ignored both because the PUC staff much preferred their less ambiguous forecast and because the decision analysis did not reach a strong conclusion that could be used by the proponents or opponents of the project. The general political judgment that the terminal was needed for jobs and secure gas supply was reflected in the Public Utilities Commission's final decision approving the terminal. This decision seemed politically predetermined. But as a postscript, technical uncertainties and disagreements about earthquake faults on the approved site at Point Conception have delayed final approval of the terminal more than two years after the federal and State decisions. And during those two years the gas supply situation has changed. There is much more domestic gas because of gas price deregulation. And the cost of LNG from Indonesia has skyrocketed, and Indonesia does not look like a reliable source for California gas. If the proceedings were being conducted again, the analyses might show a situation in which the LNG terminal should not be approved.

Moss Landing Marine Oil Terminal. The Pacific Gas and Electric Company had proposed to replace a marine oil terminal with a new larger one. As with the LNG terminal risk assessments, the "worst case" also overwhelmed "expected case" analysis with respect to this project. A series of agencies approved the project, including the Coastal Commission. The last permit required was from the Army Corps of Engineers. The other agencies had approved the new terminal because larger, newer oil tankers could use it. It would not change the total amount of oil carried to the terminal for use in the adjacent electric power plant. But larger tankers would make fewer trips, and because the facilities and the tankers would be newer and more reliable, the agencies estimated that the average probability and size of an oil spill would be decreased with the new terminal. The use of larger tankers would also decrease oil transport costs to the utility and, therefore, to electricity consumers.

But some local groups charged the project would bring "supertankers" into Monterey Bay. The U.S. Fish and Wildlife Service wrote the Corps that the project might not assure the continued protection of the endangered sea otter, whose range extends from Monterey Bay south about 300 miles. The Corps denied the permit, citing the lack of assurance of sea otter protection, the opposition of some local groups, and the opposition of the local Congressman. The Corps presented no analysis for its position. On the contrary, not only did the Corps decision result in a higher average risk of spills affecting the Bay and the sea otter, but it was explicitly based on political considerations. There were no real standards on which the Corps permit decision was based. It was an ad hoc discretionary permit, based on whether the local colonel determined the project was in the overall national interest, a notoriously vague term. The role of analysis in such decisions seems small.

Sundesert. There was much analysis done on whether the proposed Sundesert nuclear power plant was needed as part of California's future electricity supply system. But the analysis seemed to trail and be in the service of preconceived ideological positions that nuclear power plants should not be built, that there were more benign alternative energy sources, and that these plus electricity conservation strategies could remove the need for the plant. In this case the ideologies may have been absolutely correct. But I am only pointing out that they were well in place before the analysis was conducted on the project.

The controversy goes back to the charge to the California Energy Commission to determine the need for new electric power plants. The Energy Commission embarked on a major electricity demand forecasting venture, assuming that the demand forecast would indicate how many new plants would be needed. After a faulty start with an overly complicated econometric model that never worked, the Commission went to an end-use engineering type model that essentially forecasted how many refrigerators there would be in California. But the whole forecasting approach turned out to be only a partial answer to the issue of the need for new electricity generating capacity. It turned out the decision really rests on the attitude toward the risk of blackouts, of lack of enough electricity to meet peak demands. A twenty percent reserve margin, or twenty percent more total generating capacity than expected peak demand, gives much less risk of blackouts than a ten percent reserve margin. But the lower margin costs less money. Decision analysis was the right tool to explicitly lay out the various risks and uncertainties about both electricity demand and supply. Decision analysis would also force the decisionmaking Energy Commissioners to be explicit about their attitudes toward the risks of blackouts. But the Commissioners and the staff resisted such analysis, preferring to be more deterministic, to look more confident than they really were, and they wanted single numbers they could vote on, telling what electricity demand would be. They did not want to vote on a probability distribution of future electricity demand.

One reason the Sundesert plant was killed was that extensive analyses showed there were other alternatives that could meet the electricity demand the plant was proposed to meet. Again, the proper format for such an analysis is a decision analysis that explicitly discusses the probabilities of those alternatives actually being available and their costs and benefits. Instead, there was one analysis that said the plant was not needed because there were alternatives such as geothermal energy, cogeneration, and more efficient oil-fired plants. But an analyst can always develop a list of alternatives for any one project. That does not say whether the project results in expected net benefits or not. Unlike the PUC's LNG terminal "need" analysis, which showed the LNG was needed as one alternative source of gas, the Sundesert analysis reached the opposite conclusion, showing alternatives could replace the proposed nuclear plant. These two analyses could have as easily been reversed. When only partial deterministic analyses are done, they can be developed and used to justify any preconceived decision. In the Sundesert case, they ratified the ideology of the Governor, the Energy Commission and many other State officials that nuclear power should be stopped. This shared ideology had much more influence than the technical analyses. The electric utility that proposed the Sundesert plant also exhibited a strong ideological position - that it should have as part of its generating capacity a large nuclear power plant. The engineers in the company clearly wanted to be on the bandwagon with the latest technology. But as the Public Utilities Commission found, the utility really could not finance the plant nor could it even find customers for the electricity. When the ideology of the applicant and of the agencies coincide, reasons are found to move the project along. When they diverge, the project dies. The role of analysis is to support sides in the conflicts or to ratify preconceived decisions.

Oil Drilling and Anacapa Island. This is another case, like the Moss Landing Marine Oil Terminal, where the applicant had to prove the proposed project would not cause damage or unacceptable risks to an environmental resource. Chevron USA proposed to place a drillship offshore about 5.7 miles from the Anacapa Island breeding area of the endangered brown pelican. Chevron presented extensive analysis on the probabilities of oil spills from such exploratory oil drilling, the probabilities of different oil spill trajectories going near the breeding area at different times of the year, and on the behavior of brown pelicans and the expected damage that might occur if an oil spill affected the waters near their breeding area. The analysis indicated the risks of any damage were very small, as the drilling would take only two or three months.

However the Coastal Commission has already developed a guideline that there should be no drilling within six miles of the Island. The Commission had to determine, therefore, that the risks would be acceptable, but Chevron's analysis had to confront this existing guideline. The "worst case" analysis again overwhelmed the "expected case." The Coastal Commission staff constructed a "worst case" analysis indicating that at worst hundreds of pelicans could be oiled by a spill, if one occurred and traveled toward the Island. The probability of this actually occurring was about one chance in 200,000. But the pelicans were recovering from near extinction due to DDT, and the pictures presented of baby pelicans convinced the Coastal Commissioners they wanted to add no new risk to their population, no matter how small the risk. When the agency making the decision is ideologically inclined toward environmental protection, as the Coastal Commission is, as required by its legislation, and when the burden of proof is on the applicant to show no unacceptable risks, analysis has a difficult uphill road to travel, especially if the "worst case" cannot be made acceptable, no matter what its probabilities.

Ormond Beach Power Plant. Analysis had a much larger role in determining which of four alternative sites would be acceptable for siting a new oil-fired power plant in Southern California. One reason technical analysis could play an important role was the way the issue was formulated for the California Energy Commission. Under State Law, the electric utility proposed four possible sites for the plant, and the Energy Commission had to rank the sites and find at least two of them "acceptable." The utility could then use one of these two sites.

There was already a State ideological consensus that an oil-fired plant would not be objectionable. So when the issue was framed as "how do the sites compare?", analysis played an important role. Another reason was that the proceedings consisted of quasi-judicial hearings in which testimony was submitted and then cross-examined by other parties. The sites were analyzed for impacts on air and water quality, local economies and housing, archaeological sites, cost of construction, and for availability of cooling water and other resources. In this kind of proceeding, where ideology differences really do not come into play and the decision framework is well defined, analysis can play a major role. The framework was essentially a multi-attribute objectives hierarchy comparison for the four alternatives. Specialist staff could analyze each attribute, be it air quality impacts or water cost and availability, and participate in the framework. Cross-examination assured the analysis was credible. Local opponents to each site were confronted, not with a "yes" or "no" decision, but with the question, "how does this site compare to the other sites?". Thus site opponents had to participate in the analytical framework. Analysis seems to play a major role when an issue is defined as a choice among alternatives and a lesser role when the issue is narrowed to a "yes" or "no" decision on one project. The Coastal Commission had this experience when it was charged with ranking sites for the proposed LNG terminal.

Manchester Anticline Oil Wells. A proposal to drill two exploratory oil wells onshore can be as controversial and complicated as proposals for an LNG terminal or major electric power plant. Technical analysis can play a role, but in local projects such as this, the ideology of "working it out" among the parties seems more powerful. A rancher proposed to drill two wells to see if an oil field underlay an area on California's north coast near the town of Manchester. Particularly strong opposition came from environmentalists and biologists of the California Department of Fish and Game, who raised a specter of a "worst case" oil spill running down the gulches and affecting a lagoon where wild swans breed. This lagoon is about three miles downslope from the drill site. The Coastal Commission staff analysis consisted mainly of a field trip to see the site and analyze potential impacts of the drilling. In this case simple "eyeball" analysis showed the probability of an oil spill was small and that it was highly unlikely a spill could escape a containment dike and then travel overland three miles. Nevertheless, to mitigate any "worst case" accident, the Coastal Commission required a $15 million bond from the driller to pay for any environmental damage that might occur. The "worst case" analysis did not kill the project, but it resulted in a major condition on the project that forced the rancher to sell interest in the project to a large company that could afford such a bond. Again, with the burden of proof on the applicant, analysis took a back seat to more ironclad assurances that the project would do not harm. In a way, the bond was a form of compensation to the wildlife interests.

MATEP. My last case is outside California. It involves Harvard University's attempt to build a Medical Area Total Energy Plant (MATEP) at the Medical School campus area in Boston. The project was both proposed and opposed by a wide array of Harvard graduates and officials. The plant is to generate 73 megawatts of electricity in addition to steam and chilled water for the medical area buildings. But, after large amounts of technical analysis, Harvard does not yet have permission to operate the oil-fired electricity generators. After 23 days of hearings about the air pollutant emissions and much analysis of the effects of the air pollutants, the hearing officer decisionmaker decided that a level of 940 micrograms per cubic meter of nitrogen oxide was the threshhold for adverse health effects. There was much analysis on this threshhold number issue, with different numbers being considered by many experts. But all the technical analysis on this number was overwhelmed by the hearing officer's value judgment that a safety factor should reduce the number by a factor of three. Little analysis contributed to this "safety factor" judgment, which is more a political or ideological judgment than an analytical one. If "expected" values are important and all objectives being maximized, including economic efficiency, then the standard should be set at the "best guess" level at which no health effects are expected to occur - if the legislation requires that a project not adversely affect public health. The "safety factor" judgment results from a moral judgment about the distribution of costs and benefits, in this case, that there should be total assurance that there can be no chance of a risk to public health from operation of MATEP. When a decision involves this level of broad discretion, the role of analysis seems limited.

This case also shows the role of compensation for local interests. The neighborhood residents also opposed the plant. But Harvard blunted much of the opposition by agreeing to rehabilitate old housing in the area, build hundreds of new housing units, and even heat the new housing free with steam from MATEP. The steam and chilled water parts of the plant are operating, but the generators are still in the warehouse, partly because there do not seem to be any compensation mechanisms that can work with air pollution control officials. It is interesting to note that Harvard University has had little more success than electricity and gas utilities in obtaining approval for a controversial major energy facility - despite what might be considered the credible analytical resources of the University.

RECOMMENDATIONS

One reason technical analysis seems to play a small role in these and other decisions is that the major problem is really how to compensate those adversely affected and how to take care of objections raised by influential interest groups and parties, no matter what the analytical merits of these objections. The main factors are political and ideological that affect decisions on major energy facilities, and decisionmakers and staffs need to know more how to be creative and sensitive in dealing with vocal interests and with unrepresented interests that should be involved rather than how to conduct technical analyses.

I do feel, however, that it is important to lessen the roles of ideology and single professions in energy facility decisionmaking. My reason is that single issue ideologies and narrow professional viewpoints can cause outcomes that forego major benefits or cause major risks that are unforeseen. For example, the siting of nuclar power plants in populated areas was based on the confidence of electric utility engineers that the risks from such plants could be minimized and safety assured. That optimism was not justified. On the other hand, total opposition to nuclear power in California is resulting in continued operation of oil-fired power plants in urban areas with heavy air pollution problems. A systems or decision analysis perspective is needed to consider all potential factors and outcomes. When single project decisions are framed as a choice among alternatives, and when all risks are at least considered, the roles of ideology and the single professions can only be decreased. Therefore it seems extremely important that decisionmakers and staffs be at least exposed to the uses and values of systems analysis and decision analysis or that they have the credible services of such analysts. Applicant energy companies also need such analysis. Too often their project proposals seem arbitrarily developed. Companies get into most trouble when they propose a "set in concrete" project for one site without having explicitly gone through systematic analysis of project and siting alternatives. But most professions yearn for certainty, confidence and credibility. Most people see issues as "black or white" in relation to their ideologies. Ideologies are a handy shortcut and a popular basis for arriving at conclusions about energy projects. But uncertainties and risks are endemic to the energy field. Systems analysis and decision analysis are needed, even on a simple level. The only way to make people a bit more comfortable with such analytical tools is to teach them in a popular way to college students, as part of a liberal education, and to require analytical courses in professional schools, particularly law schools. Many lawyers seem involved in energy decisions on all sides of the issues and as administrative law judges and as decisionmakers.

Another way to enhance the role of analysis compared with ideology is to develop as many predetermined standards, regulations and groundrules as possible in proceedings divorced from individual project decisions. A major problem for LNG terminal proposals has been the lack of thoughtfully developed nationwide federal safety and siting standards and regulations for such terminals. Instead, each local government, such as the small City of Oxnard, and each State agency has had to deal with complicated risk issues that far exceed their analytical capabilities. When standards apply to a project, the issue is whether the project meets such standards. Analysis plays an almost deterministic role in such decisions, and issues revolve over technical conclusions rather than ideological viewpoints. In a way, this is a self-fulfilling conclusion, because standards can only really be set for technical aspects of projects - such as how far an LNG terminal should be from different numbers of people or how the thermocouples should be designed. It is difficult to develop preset groundrules on determining whether an LNG project is "needed" in an evolving energy supply and demand situation.

Another way to enhance the role of technical analysis would appear to be to allow all testimony to be subject to cross-examination. However, I am not sure of this. In general, experts submit testimony and are cross-examined. Then a hearing officer or administrative law judge assesses the testimony and submits a recommendation to the decisionmakers. But the decisionmakers in such proceedings seem to have many sources of information and impressions, particularly the press, personal staff, and other officials and friends.

Cross-examination can enhance the role of experts and technical analyses in parts of the decisionmaking process. But even then its role depends on which interests play roles in the decision through other channels.

With respect to public participation, I have noticed that the organized interest groups such as the industry associations or environmental groups can gain access to the decisionmakers and the process no matter what the character of the decisionmaking process, be it formal judicial proceedings, public hearings or a single administrator protected within a large agency. The character of the process does affect the access by local affected interests such as neighborhood groups and local economic and environmental interest groups. But in California even these groups generally can mobilize experts and lawyers and staff help when dealing with an energy project, particularly one such as an LNG terminal. These groups can strongly affect a decision that must be made by a local government decisionmaker. When the decision is at the State level, such as the Public Utilities Commission, then statewide groups and politics can affect the decision much more, and the decision is removed to a large extent from local influence. This was the case when the California Legislature removed the LNG terminal decision from local governments and placed it with the PUC. Federal politics then affect federal officials. Therefore the more levels of government that must approve an energy project, the more likely there is to be a divergence in politics or ideology among the permitting agencies. An administrator in Washington DC will have much different perceptions of the risk of an LNG terminal to the people of the City of Oxnard than will the Oxnard City Council, which is elected by those people.

In general, the analysis seems to have more credibility the higher the level of government. The Department of Energy staff had dealt with three or four LNG terminal proposals before they dealt with the California LNG terminal project. They had done analysis before, developed groundrules, and had credibility with their Administrator. The City of Oxnard staff had never seen an LNG terminal, and they had to rely on consultants for advice. So another way to enhance the role of analysis is to have decisions on major energy projects made by levels of government and agencies that have developed credible experience and expertise and staff. This probably means higher and more removed levels, which can decrease the access of local interest groups to the decisions.

There are no clear ringing recommendations here. I believe that technical analysis, especially systems analysis and decision analysis, should somehow set the framework for decisionmaking on major energy projects, especially ones that present public safety risks. But that will not happen until the staff of the International Institute for Applied Systems Analysis and other broadly trained analysts are themselves agency decisionmakers and staff and such analysts are directly involved in these decisions, to keep the lawyers, engineers, biologists, financiers, economists and planners explicitly aware of risks, uncertainties and interrelationships.

REFERENCES

Ahern, W.R. "Energy Facilities and the California Coast," Proceedings of the Coastal Zone 80 Conference, American Society of Civil Engineers, New York, N.Y., November 1980 (forthcoming).

Ahern, W.R. "California Meets the LNG Terminal," Coastal Zone Management Journal, Vol. 7, No. 2-3-4: 185-221, 1980.

Bethell, John T. "How Does It Feel to Have a 73-Megawatt Headache?", Harvard Magazine, 19-29, July-August 1980.

PRESENTATION BY WILLIAM AHERN

I will tend to be quite brief. I totally agree with Mr. Schwarz when he said he had the feeling that in these cases there is more difference in style. I find more of a difference between the professions represented around this table than between the different countries. I find myself almost holding hands with Mr. Campbell when Mr. Mehta gets up here and when Norbert Dall asks for more information, or when, those that I characterize as analysts or academics go on to some point. So I find myself with Mr. Oseredko, Mr. Campbell, Mr. Clarenburg, Mr. Vincent, and sometimes Randy Deutsch (all of government agencies).

I almost sit here vibrating. About every hour I feel I have to go to the bathroom, and if I do go, then I miss the telephone ringing and I cannot stand it. Its incredibly quiet here [in Laxenburg]. No people calling in from the outside with a daily crisis. You will have to excuse me for being extremely befuddled and confused, particularly at the end of three days. You kind of sit there and say, "Well, here are people talking about what we do and they are studying us, but they are trying to learn how to ride a bicycle by looking at movies, or reading books about it, instead of getting on the bicycle and doing it themselves. They have not been on the 'Hot Seat' as we say in America."

I very much love to reflect on these different cultures and styles as they relate to professions or as they relate to what someone does everyday at work. I find, to reflect on the first point that John Lathrop brought up when this whole meeting started, that one objective was to figure out the truth of these cases, if I remember correctly. I found more about the truth of these cases over lunch than I have in the talks. Which I find *typical*. I think the way that all the decisions were made about these different facilities--the Yerevan, St. Lasiare, Point Conception, Mossmorran, and the Dutch one--is that people of stature, influence or prestige, talk to each other about this project. If they shared the same attitudes, the same values about the project, the project went; if they did not, it has not.

On a basic look at the merits of those cases, the Yerevan facility appears to be an absolutely obvious thing to do. A good site for a good purpose, even if Mr. Oseredko was trying to do that in California he probably would get most of his permits and only have two or three law suits. I think that would probably be a very straightforward project. If a Soviet Ministry or a French Ministry had proposed the Netherlands facility, particularly the artificial island, I think it would have died a very natural death because of what other ministries would have thought about it; and that would have bubbled up through the process because all of these countries have checks and balances just like the United States. It seems to me that in other ministries in some countries, we do not quite see exactly what is going on.

In the United States, the California process looked like it was very public. I hold that most of it was theater, but in many ways the decision was made in exactly the same way as it was made in the Soviet Union or in France, or in the Netherlands or even in Great Britain, with what I always view as something of a clubby atmosphere in making these decisions, as we heard earlier. But Governor Brown of California was on the phone to the publisher of the *Los Angeles Times*, and the Chairman of Randy Deutsch's Public Utilities Commission is from Yale, and was a Yale roommate of the Governor. The labor unions were for the terminal, the gas utilities and the big industries were for it, and the environmental groups were fairly neutralized on it because it was gas. The only reason the environmental groups did not like this decision is what it might do to the California coast. The environmental groups have their ministries, one of which is the Coastal Commission, which is generally a check in our system of checks--checks are where you can stop something and balances are where you bounce off each other. My ministry may have been a check, but we got balanced on this one, because the jurisdiction was taken away from us. We could no longer be a check. In this case, even in what is called our litigious society, the lawyers got balanced out too. Special legislation was passed so that the lawsuit on the Liquefied Natural Gas terminal had to go directly to the California Supreme Court. Randy Deutsch has been pounding back lawsuits from the Indians and the environmental groups for months, quite successfully I believe. So that what we have seen in the United States is actually, in my mind, quite wrong. Of all the cases studied, the only one I still do not quite understand, of course, is the California case. As you have seen the Governor was for it, the Vice President was for it (as Norbert Dall said), the publisher of the *Los Angeles Times*, large industry, and large labor unions were for it. You might wonder why the damn thing is not built.

Well it is not built, in my personal opinion, because times changed. It took the gas company and the gas utilities a couple of years to bring all this political support together to get rid of us "checks"–the Coastal Commission, the lawyers, the environmental groups, etc. The situation during that time has changed so radically that I do not think they want the project anymore, but are too embarrassed to say so, because they spent so much money getting the legislature and the governor to support the project. They are hoping that more earthquake faults will be found to end the thing, much like the Dutch project, which I understand has just simply gone away.

Now let us turn to the second question that John Lathrop raised, "what is the role of analysis in all these decisions?" You might guess from what I said at first, that you can only look at the role of analysis by figuring out what were the factors in these decisions. And once again, I tend to believe that it was the important people that matter talking to other people and I would like to illustrate that by one example: my commission, the California Coastal Commission, was given the role to rank sites for a liquefied natural gas terminal. When you think about doing that, you can only be horrified by the responsibility, because if a government agency finds potential and alternative sites for a big expensive hazardous thing, ranks the sites–1,2,3,4,5--and then makes them public, as is the case in California, where the theater would be fairly heavy in all the proceedings, you can imagine the possible repercussions.

Well, we went out and did this, got a taste of what it was like to be a gas utility or a gas company. We identified, for example a site in Malibu. Malibu has some of the most bright and attentive public in the country. We identified a site there in a canyon, sort of out-of-sight, a nice little canyon and you could put a whole terminal there if you filled the canyon in, and we thought it was not bad. We are supposed to protect the coast. I had to justify that site as being one of the five sites to about 300 people from Malibu, and, as you know, Linda Ronstadt lives at Malibu, and she is a good friend of the Governor. It was one of the most unpleasant meetings I have ever had. In fact, I had unpleasant dealings in five different locations.

Well, what was the role of analysis in this project. This is a perfect project for multiattribute decision analysis. Five perfect sites. You can compare them on environmental risks, safety problems, the cost of the sites, the technical problems. It was a classic. In fact, I have not told this next bit of information even to Ralph Keeney.

Ralph works up the street from us, and he came over to our office, as I understand, and talked to some people on my staff and he asked, "Would you not be interested in a nice multi-attribute analysis of these alternative sites?" Well, my staff came to me and said, "Bill, this guy is from Woodward-Clyde and, gee, he sounds good. Should we not hire him to help us do this?" And I said "Absolutely not!" And it is not because he is not an excellent analyst, but because he does not work for me and therefore he would be out of my control in many ways, because Ralph talks to people such as yourselves. He has got his own principles to uphold, and he would not give us a report that we could put under the shelf because Norbert Dall would know that we had contracted with Ralph Keeney to do the report, and he would want to see it--no matter what it came up with, and that is not something we wanted.

Not only did we on the staff not want it, but our Commissioners did not want it. Actually I am trained in this stuff myself, and I tried to talk my staff into doing it as they, at least, work for me. And if they put a number in, I did not like, I could jiggle it around. They were so appalled at the idea of doing this.

This is a major problem in the role of analysis. By analysis I do not mean technical analysis, but comprehensive analysis that actually gives you a format for looking at what a final decision should be. And the reason our Commissioners did not want any such thing was because they did not want to be explicit about their reasons for making their decisions. THAT IS THE LAST THING they wanted to do. One reason for that is our Commission had to debate for about four years as to whether California should have a general policy that a liquefied natural gas terminal should be in an already industrialized area because it's an ugly thing that ought to be where all the refineries are. Or whether, because it's a hazardous thing, it should be in a lovely part of the California coast and screw that up but not put anybody's life at stake. It's what we call the "Birds vs. People" dilemma—which is an incredible value tradeoff, and is absolute murder. Our Commission had said (actually, they came out first in favor of birds), "put the ugly thing in Los Angeles, how could it be noticed?"

Then a few more studies were done, however, about liquefied natural gas, and people started to figure, and someone came out and said an inflammable gas cloud could travel 50 miles. The Commissioners then looked and said "My God, not only could that affect Los Angeles but it might even get down to San Diego, or someplace even worse." So we started to get concerned about this, and then they thought, "but we cannot put 60 foot high tanks out in a beautiful part of the coast." It was one of the most awful debates that our Commission went through. They finally wound up saying, "Well, when there is an application for a Liquefied Natural Gas terminal, if the gas company can prove to us that it is safe enough, then it has to be built in an industrial area. But if they cannot, then they have to build it in a remote area of the California Coast." Well, when our poor gas company learned that they would have to convince the Coastal Commission that it was safe enough, they knew that it would have to be in a remote area. Then when they knew that the remote place would be a place near and dear to the Coastal Commission because it is remote and undeveloped; they knew they probably would not get a permit at all. So we were probably going to be a check, and that is why the jurisdiction was taken away from my Commission.

To get back to the role of analysis, I could not convince my staff to do a multi-attribute decision, so I did one for myself but kept it in my drawer. What I firmly believe analysis does is (1) help you to analyze the factors, to be explicit to your own self about what you care about and what your value tradeoffs are, and then, once you arrive at your decision, (2) it helps you to kill the opposition. And the reason it helps to kill the opposition is because you have thought about some things they have not considered, and you can always bring up "that you care about this, but you do not care enough about that." You then put them into a framework or into a process where a decent decision can come out. But I am extremely reluctant to have any outside party do that analysis, even if it is developed within this framework, because the decision is affected by a number of factors that you do not want to be explicit about. Like the call from the governor to your commissioners.

So what I did for our commissioners was what I call a "Rating and Weighting" Chart, which is something like Mr. Clarenburg put up. He had all these different factors with pluses and minuses next to them. In our case, instead of pluses and minuses we left them blank. Then we xeroxed them and handed them to our Commissioners and a number of them filled them in and kept them in their drawers. You could see during the public hearings that they would change their original numbered rating. I think they used it quite responsibly.

Therefore, I think the role of analysis is extremely important. One reason some of our best analysts do not have important roles with respect to decisions is that they want their analysis to be in the public arena. As you know the academic style, is to send reports out for periodic review. Agencies with their own constituencies and decision makers who do not want to be explicit about their value tradeoffs are very reluctant to have that kind of thing happen.

Finally, just a few reflections on the role of analysis. First of all, I was quite impressed. There seems to be a higher role for analysis; the higher the level of government at which the decision has to be made. And not surprisingly, I was most impressed by the level of analysis that seemed to go into the Soviet Union's decision on these projects, which includes a comprehensive plan that could be compared to Norbert Dall's call for a comprehensive industrial siting plan in California. The linear programming and the input/output models require that a vast amount of analysis go into that kind of decision.

There seems to be more of what I would call "objective analysis" when you are developing a plan or guidelines for standards rather than an *ad hoc*, one time, "yes" or "no" decision such as the Mossmorran project. When you have a "yes" or "no" decision the role of analysis gets absolutely lost in the politics and the conflicts about the situation. I was amazed to see analysis of the 10^{-6} type that was totally discredited in California, because the gas company consultants did it and it was then used on the other side against the project. All I can tell you is that I wondered if either party would have used the analysis they had, if it had shown different numbers. I really doubt it. I do not know if its just coincidence that the gas company's consultants came up with 10^{-9}, and Mossmorran consultants came up with 10^{-6}. I am not sure. All I am saying is that it has to affect the credibility of the analysis. Because it is associated with a very strong opinionated party in the proceedings, or someone with a real stake in the proceedings. Legitimate stakes, no doubt about it, but the analysis seems to buttress preconceived positions, and you can find analysts on both sides. When decision makers see this on both sides, it tends to discredit analysis in general, that has been my impression.

Analysis as presented here in many ways is another value laden interest group just as value laden as astrology, or "small is beautiful," or "let the elite make the decision or the king", or "profit maximization." I tend to view analysis as another interest group. One which I am very much in sympathy with and think should be used. Therefore, my hope is that a good competent analyst will be inside the agencies. In this way the agencies can hopefully have a little more trust in their proceedings. In the United States, analysis, particularly quantitative analysis, has been tremendously discredited, partly because we hear comments like, "the gas company bought that kind of analysis." And partly because of Robert McNamara and the Viet Nam War where the body counts and computer models, input/output analysis, linear programming were used in a very naive exercise where they did not take into account a large number of other considerations like the anthropology in Viet Nam, political implications, and other relevant constraints. Today analysis is still very much discredited in the United States. I think it should be used more. I say the way for it to be used more, is for many of us to switch positions for a short period of time, to have a little cross-cultural exchange. I feel that its very important that we in agencies spend a little time doing what IIASA does (I would love to switch positions for a year or so), and that researchers such as those at IIASA spend a little time doing what we do.

DISCUSSION COMMENTS

NORTON: I found Dr. Ahern's paper very interesting. As a plot for a movie it could be named "Much Ado About Nothing," and be a "Rank" production. In his paper, he reflected on a variety of energy projects and on the relevance of decision or system analysis. I would like to look at a few other examples of problems, which would lead me to come to a somewhat positive, but not resounding, note in favor of systems analysis as a method for approaching these problems. These examples illustrate paradoxes involving local interests.

While there were peaceful anti-LNG rallies being held in Staten Island, the only violence that occurred was a protest demonstration where the same locals were against the establishment of an amusement park about 4 miles away. It is an odd sense of priorities. Despite the New York City opposition to the Staten Island terminal (which was abandoned for lack of LNG supply and not due to local pressures), we did get initial approval for an expansion of our Boston Import program. It was before the Federal Energy Regulatory Commission for final approval, when New York City intervened in order to ensure getting its share of the LNG. It seems that sometimes the shoe fits someone elses foot rather than our own.

New York, however, does not take a back seat to Boston when it comes to local self interest. Following World War II, when there was a spirit of working together for important projects, a dam was built in western Massachusetts to form the Quaban reservoir. This dam was to supply fresh water for Boston, as well as other eastern Massachusetts cities well into the 21st century. Even though seven villages were evacuated and the site was completely inundated with water, this was simply a price to be paid for the greater good. This was considered a model of long-range planning. However, this fall the town of Amherst, which is the site of the University of Massachusetts, serving 10,000 students from Massachusetts, as well as New England, ran out of water. The students were sent home until it rained or the crisis was otherwise resolved. Since Amherst is only a stone's throw from the Quaban reservoir, the town naturally asked to share in some of this long-term water. The reply from the administrators was "NO!" This is a example of a public project not operated in the public interest.

Much has been said about the use of systems analysis for siting LNG facilities in the U.S. For example, Congress passed a law, to be implemented by the Department of Transportation, to regulate the siting of LNG import terminals. I can only ask, "What terminals?" The terminal in Boston is a small installation serving a unique peak shaving market and no expansion is foreseen. The terminals at Cove Point, Maryland, Savannah, Georgia, and Lake Charles, Louisiana, can, with modest expansion, handle any quantity of LNG that the Department of Energy is likely to approve for import.

As far as the beleagered California terminal is concerned, it conceivably could lose its potential supply of Indonesian LNG to Japan, and the modest amount that is available from Alaska will not justify so expensive a terminal. It is quite appalling to think that over a quarter of a billion dollars may have been spent for nothing. A quarter of a billion dollars is ten times the total construction costs of the Distrigas Boston terminal. In this case, I think of analysis as paralysis.

Yet, what is the role of systems analysis in the future? I think it may be useful for existing terminals, but I do not think it will prove useful for siting purposes. Yet it can be valuable in the area of risk analysis. A broadly-based nation wide analysis with regard to siting problems could offer some insight and understanding with respect to more palatable planned siting, say in Texas or in Oregon. But it also might indicate some surprising results such as "you really should not be siting. You should be reducing world population" or "you might look at what your perception of the quality of life should be." That would be a set of troublesome thoughts to find scurrying about as the systems analysis raises the rock of our present preconceptions. The real benefit in risk analysis is when it is relatively constrained, where you can work with the system, namely, an existing plant. Historically, in the U.S., we started when there was no jurisdiction. There were no laws--it was go out and do it like Marshal Dillon out in Dodge City, Kansas. The Distrigas site was determined by economic logistics, markets, port, water transportation, truck transportation, pipeline connections, and, incidentally, the availability of the site. There were several that were looked at, but it was nice to have a place that you could buy. The safety was considered in the context of "basic good engineering practice" with reference to the only existing code at that time, the NFPA-59A. Now I agree that "basic enginering practice" is not a good term, but if used conscientiously, it produces some excellent results which are sometimes long standing, not guaranteed, but still not too bad.

At the point when the terminal was in the design stage, the President of Cabot Corporation felt that LNG terminal was different from a petrochemical terminal (in fact, different than anything the corporation had been in before), and he appointed a group known as the Cabot LNG Safety Review Committee. This is an oversight group consisting mostly of outside, world-wide recognized technical experts who had a open ended charter to be sure that the plant was designed and operated safely. The committee reported only to the president of the corporation, and there was no real or imagined pressure that might apply to an employee of Distrigas or an employee of Cabot Corporation. This committee was patterned after the Nuclear Reactor Safety Committee of the AEC, because two Cabot Corporation top executives did have nuclear backgrounds. The terminal needed the committee's approval to begin operating. Approval was later given to the LNG terminal in Massachusetts and to the Staten Island terminal which at that time was 99.5% complete. (Now after many years it is probably about 92% complete as it begins falling apart unused.)

Complementing the LNG safety review committee, we have an inhouse engineering review. We also have an inhouse safety department that undertakes safety systems engineering, major hazards analysis, and fault-tree analyses. How good these analyses are depends on how conscientiously they are done. On top of this effort the Three Mile Island incident prompted a total review of our emergency response plan. We collared various and asundry government people and dragged them (kicking and screaming) to agree that there ought to be a program where everybody works together before the event happens. I think that is beneficial. We also formed a grassroots Process and Safety Review Committee, a mixture of inhouse and outhouse people–the outhouse people are the consultants. Their main concern was seeking out and closing paths by which small incidents or accidents could escalate and cascade into major incidents. This program has been completed, and we are implementing the results as rapidly as we can.

The inhouse safety review is a continuing activity. It must be repeated with different people, with different ways of looking at the problem in order to keep the terminal up to date. As an example, our original plant was designed in 1969 for seismic purposes using the so-called uniform building code. By 1970, somebody changed the map on the uniform building code zoning area, putting us in a more severe earthquake area. So at the stroke of a pen, we were out of accord with the code. We hired our own "independent California consultants" for an independent assessment of the earthquake maximum frequency and intensity. We took these results, analyzed them, the design of the tank, and felt that there was no problem. This study was completed before the tanker arrived. The tanker would have been refused had that analysis proved otherwise. We updated the study, and reviewed it in the mid-70s. In mid-78 new studies came out on the earthquake probabilities in Massachusetts, some of which indicated the possibility of more vigorous earthquakes. Soil mechanics also brought a better understanding of when you could get liquefaction of soil. So in 1979 we brought in our consultants from MIT to reappraise our seismic resistance. The work is approaching completion, and at the moment, it looks favorable.

In closing I would like to quote Dr. Ahern again from another paper of his, *California Meets the LNG Terminal*. "Rarely did consultants resolve the safety issue. On the contrary, there seems to be a natural tendency among consultants to define any unknown and call for more research." I think along with "Murphy's Law" and "Parkinson's Law", that might be listed as "Ahern's Law".

LINNEROOTH: You referred to Marshal Dillon as symbolizing the unconstrained "wild west" of local affairs--the good old days. I would like to mention that he is now living on one of the ranches next to the Point Conception site, and he is one of the protesters.

KEENEY: In reference to Bill's [Ahern] talk, doing analyses and reporting analyses are very different things. I realize in many cases, one implies the other. But there are those cases where one does *not* necessarily imply the other, that is, *doing* the analysis could be worthwhile, even if it was not explicitly indicated to everyone else. Many in the game of facility siting would be delighted to have another party do an analysis, honest and open, and lay it out on the table. Yet they want to keep theirs right up close to the vest even though they would not mind seeing theirs.

One of the things, for better or for worse, which is leading to an increase in analyses are the new rules that require those wishing to build a facility to indicate their reasoning, the uncertainties, and the value judgments on which they have based their request. It then follows that those who are ruling on the sites will have to refer to the analysis in making their decisions.

CLARENBURG: I would like to comment on the statement made by Ahern that large projects are decided among people of influence in the country. When they agree the project is safe it will be approved no matter what other parties say. This is not our experience in the Netherlands. In the Rotterdam area, some major projects have been turned down on considerations of environmental pollution. One steel work was refused simply because it would introduce into the area a new type of air pollution from thermal aerosols, which, combined with existing air pollution, would create synergistic effects. And other smaller projects were turned down for various reasons. Projects at least in my country are never precooked. There are still too many outside checks on the system, so that you could not proceed in the informal way that Ahern has described for California.

DALL: I think Bill [Ahern] raised some good insights concerning other countries' decision-making, but he missed an important point about his own. He only looked at California and not the encompassing federal system of the United States, where there is, in fact, the due process provision that Professor Ravetz referred to in his presentation. In the United States, the intervenors in the Point Conception project have sued in the federal courts precisely because we were prevented by the rashly adopted California LNG Terminal Siting Act from obtaining substantive legal remedies in the state courts. A portion of the federal agencies' decision has recently been remanded by the federal courts, whereas the California Supreme Court refused our petitions. The United States' collective decision-making process, thus, is considerably more comprehensive--and protective of parties' due process rights--than the informal influence that Bill Ahern described in California, i.e., where the Governor calls the decision-makers in the middle of the night to press his case.

THOMPSON: This argument appears to be the same the world over. The Russian plant would have got permission in California and the Netherlands Artificial Island would have been turned down in Russia as it was in the Netherlands. Would Mossmorran have got permission had it been in California?

AHERN: Mossmorran raises exactly the same issues as Oxnard--putting something that is regarded as hazardous in an industrialized, populated area. If there were a perceived need for the project--employment, energy supply or whatever--then Oxnard would be the site for the same reasons Mossmorran now is. Most state agencies, people anyway, were in favor of the Oxnard site.

KUNREUTHER: Just a quick follow-up on this point. It would be interesting to see whether or not a citizens group in Mossmorran would be able to turn around the whole process. It appears that citizens groups were able to do this in Oxnard. With every group almost in favor of locating in Oxnard it was incomprehensible to me that they did not. In your talk you alluded to the fact that there may have been behind the scenes concerns which indicates that perhaps they really did not want to build the plant anywhere and maybe were looking for a way out. To turn the situation around; do the Mossmorran people see the possibilities of an Oxnard situation emerging there where a citizens group could change the decision?

AHERN: Because of our systems of checks, the City of Oxnard had a veto on the thing, and so did the Coastal Commission at the State level. If 100 mothers from Oxnard had, with their children, come to a Public Inquiry with a slide show of fireballs over the city, my Commission would not have put it at either Mossmorran or Oxnard. But that is because we have three levels of checks on the project.

MEHTA: A citizens group in the UK has, in fact, no right of appeal or reconsideration of the decision as you do in the United States.

AHERN: But as you said, if your local mayor or city council had to make the decision, they would have approved it.

MEHTA: Yes, that is correct. This is one of the problems that the citizens group was facing. We had, in fact, no official support whatsoever. You had one small minority local group who were fighting, not only the big companies, but the local authorities, the central government, the industry, and the unions. To come back to the point Mr. Clarenburg made earlier, if there had been a referendum held in the area, I have no doubt as to which way it would have gone. It would have gone for the development, but that does not make it right. If we could have gone through some higher level of decision making where one had a chance to adequately evaluate the safety issue, then there would have been a greater sense of fair play.

SINCLAIR: In this case we are talking about the city council, which administers a local, small area which contains two or three towns.

BULL: The effects of blighting, as soon as you declare a site as a possibility, seem to have quite a major economic effect on the local community. What are the effects of blighting on the site that you chose?

AHERN: Having five sites had several effects. It caused incredible dilemmas both to local groups and statewide environmental groups. Instead of a "yes" or "no," it was a choice. Given that a terminal was needed, where was the least damaging site? We were very sensitive to phrase it that way. Nevertheless, we began by approaching the people of the State of California, and we got 82 sites. People in Santa Barbara County said look at San Diego County, four ranchers wanted the terminal on their ranch, etc. We evaluated all 82 sites and maneuvered it down to five and each of those five was blighted--got everybody quite upset. We spent a lot of time explaining that it was a comparison of five possible sites. Every local government and local group came in and explained why their site should be ranked last, and the other sites should be ranked above them. It turned out for our Commissioners that all the information, and more, came out in that planning process. And now the sites are permanently blighted because people will point to the Coastal Commission which was supposed to protect the coast, but declared that of the 82 proposed sites this one was one in the top five for an LNG terminal.

DEUTSCH: Its an interesting thing when you finally put a specific question to those protesting groups referred by Mr. Ahern in an effort to establish a firm position, because certain groups such as environmental organizations have been forced into, and have become used to, being negative in their approach. I remember a specific Federal Proceeding where the Sierra Club attorney had for months said "this site is no good, that site is no good, We want offshore siting, no proposed site is any good." The judge finally became angry and said, "Alright! You come in tomorrow and you tell me the official position of the Sierra Club on where you want to site it offshore." The attorney did not show up the next day.

LATHROP: I was fascinated by the parallels we were starting to draw between Mossmorran and California. However, it never was clear in my mind if we could pin down what crucial differences might exist. For instance, the Dalgety Bay Action Group could not convince its local government council of the dangers of a terminal, but the Oxnard concerned citizens groups did persuade many of the groups involved in the decision. What is the difference between the two cases?

AHERN: In our proceedings the burden of proof was on the gas company to prove that it was a safe enough place to put the terminal. And our commission would have to find that it was safe enough to put it there, otherwise it had to be at a remote site. The gas company could not prove a case for acceptable risk where the risk showed the probability of a serious accident to be 10^{-7}.

MEHTA: We would have been quite happy with the 10^{-7}, or 10^{-6} or 10^{-5}, even 10^{-4}. The risk to our community was of the order of 10^{-3} as opposed to the 1 in a million which was accepted at the Public Inquiry hearing to be the accepted norm. It is the manner in which the decision was taken that, I think, is the biggest difference between the California and the Mossmorran siting process. If we had some system of appeal, we would be quite happy with that, or we could have called upon the oil companies or the government agencies to institute the type of analyses that they carried out on Canvey Island, and which, I assume, was the sort of studies that went into the California site before any decisions were reached. We would be quite happy to accept that, but in fact no such assessment was carried out by the oil companies or HSE. And the assessment that was carried out was undertaken by the affected community.

CAMPBELL: I think you really do have a form of appeal, though not described as such. In the Mossmorran case a planning application was made, and, due to the concerns of your group as well as other considerations, there was a Public Inquiry. There is, in fact, a system whereby controversial and planning matters are considered. That the Public Inquiry did not come out the way you wished does not mean that in fact, the matter was not considered, and that the processes are not there.

MEHTA: That is a wholly fallacious view of what the Public Inquiry system is all about.

CAMPBELL: What if you had a system of appeals where you were also unsuccessful? Unfortunately, these things do not turn out the way everybody wants.

RAVETZ: I think in fairness to the Mossmorran people they have framed the logic of their case quite carefully. The logic of it is that in two years, let us say, you have a very speedy Public Inquiry, where the major issue was settled on the basis of very scanty information. Two years subsequent to that time a lot more information came in which had not been officially recognized. I think the group feels this is genuine information of real substance which was not available at the original time of the Public Inquiry which deserves a proper hearing.

BARRELL: That information was, in fact, sufficiently recognized and there is documentation to that fact. There are a number of other things which could be said about that Inquiry that are of real relevance. However, as I explained earlier, Niall Campbell and I are a bit constrained as to how much we can talk about it.

KUNREUTHER: I was really struck with what Bill Ahern said in response to John Lathrop's point about the burden of proof. What we really found is that the gas company had the burden of proof to show that something was acceptably safe, and everything fell on their shoulders and if they could not do it, then you found that Oxnard could not pass as a site. In the case of Mossmorran, the citizens group had the burden of proof to show it was unacceptably safe, and as a result, unless you can make that case you would not go through the whole process of the public hearing.

MEHTA: I think you can go further than that. It is not just a question of whether the burden of proof should be on the company or the local community. From what was said a while ago, it also seems that the burden of proof is on the local community, rather than on the people who are being paid to look after the public interest.

FUTURE DIRECTIONS FOR SITING DECISIONS

A.C. Barrell
Major Hazards Assessment Unit
UK Health and Safety Executive

In this paper I set out some personal views about the ways in which the process of siting liquefied energy gas (LEG) facilities in the U.K. might change and improve over the next few years. I will start by describing in some detail the existing arrangements in my country as these may not be familiar to other participants at the Task Force Meeting.

The important, if obvious, point to make right at the beginning is that the decision about the siting of any LEG facility will be directly influenced by its likely impact on the immediately surrounding population and countryside. I intend to discuss the impact of the health and safety hazards of LEG facilities on the work-people who run them and the public who live nearby. However, other matters such as noise, pollution, visual impact, and employment opportunities may be just as important in terms of local planning and a decision whether to proceed.

LEGISLATION ON SAFETY HAZARDS

In the U.K. LEG facilities, like all other work activities, are subject to the comprehensive general provisions of the Health and Safety at Work Act 1974. At the present time there is no specific or detailed legislation for LEG facilities and similar hazardous installations. However this position is likely to change in the next year or two. Readers may recall the explosion at Flixborough, England, in 1974 in which 28 people died. This accident led to the setting up of an independent Advisory Committee on Major Hazards, one function of this

Committee being to determine the need for future controls in the major hazards field. Following recommendations of the Advisory Committee [1, 2], a draft consultative document entitled "The Hazardous Installations (Notification and Survey) Regulations 1978" was published [3]. The substantial body of comments submitted by industry, unions, local authorities and many other interested parties have now been considered and certain amendments are currently being discussed. If these Regulations become law, their effect will be that firstly occupiers of certain installations where potentially hazardous activities are carried out will have to notify the Health and Safety Executive (HSE) and give certain factual information, and secondly in certain cases, perhaps 10% of the total, they will also have to carry out a hazard survey and report the results to the HSE. The materials within the scope of the Regulations are mostly either highly flammable, highly reactive or highly toxic.

There is little doubt that an LEG facility, by virtue of the quantities of flammable material involved, will qualify for the more onerous requirements of the Regulations, namely the production of a hazard survey report.

The proposed Regulations outline the particulars to be included in a hazard survey report. Some information is factual: process information, flow diagrams etc. Some information will only be elucidated by the company as a result of the surveys: including the factors leading to the release of either pressure energy or very substantial amounts of the hazardous substances concerned, what is being done in terms of process precautions, systems at work, management arrangements to control and prevent any loss of containment, and finally some consideration of the emergency arrangements necessary if despite everything there is still a loss of containment.

After assessing a hazard survey report it will be open to the HSE to ask for a detailed report of the magnitude and probability of any hazardous event. It will thus be in companies' own interests to ensure that the initial hazard survey is sufficiently comprehensive, and that the report sent to the HSE adequately reflects the thoroughness of the survey.

The survey report is not of course an end in itself. It is a means by which the company and the HSE can identify the action needed to ensure as far as is reasonably practicable that a major accident with serious consequences does not occur.

A more detailed account of the preparation of hazard survey reports is given elsewhere(4). Very few of the reports themselves have so far been published in the open literature but arguably the most important to date is the one on Canvey Island(5) which has aroused considerable interest and comment. This Report recently underwent a searching examination at a major public enquiry on Canvey Island and I will comment on some of the lessons learnt later in this paper.

The special legislation being considered in the U.K. is now matched by a draft EEC Directive on the control of certain major accident hazards. This Directive may well be adopted within the next few months and it seems very likely that LEG facilities will be within its scope.

PLANNING ARRANGEMENTS

I have dwelt at some length on the controls for the safe design and operation of LEG facilities as they are an important part of the public debate on the siting of such facilities. Let us now turn to the planning issues. In the U.K. the Health and Safety at Work Act and draft Regulations described above, impose general requirements subject to "reasonable practicability", a concept which makes it necessary to take account of the costs of safety precautions whether those costs be expressed in time, money or difficulty. It follows that even when LEG facilities meet the requirements of the Act and the proposed Regulations there will remain a small residual risk, however remote, of an incident with the potential to harm not only the work people but also members of the public within the vicinity. It is necessary therefore to consider the siting of such facilities in relation to surrounding populations and the separation distances that might be thought advisable between facilities and houses, schools, shops, hospitals, playing fields, etc. Under the planning legislation in the U.K. such decisions are made by the local planning authorities, although they can obtain advice from the HSE as described below.

Listed Major Hazard Sites

In 1972, as a result of the growing awareness in the U.K. of the hazards inherent in large chemical plants central government entered into a voluntary arrangement with local planning authorities. The arrangement is that the bulk storage and usage of certain hazardous chemicals is notified to local authorities who can in turn ask the HSE for advice on their safety when planning matters are under consideration. These sites are known as Listed Major Hazard

Sites. Two particular occasions on which planning authorities seek advice from the Health and Safety Executive are in relation to applications to build new major hazard chemical plants (including LEG facilities) or extensions to existing ones, and proposals for building houses, schools, or hospitals in the vicinity of such sites. Not all such applications are referred to the HSE, however, as this is a voluntary arrangement.

Major Hazards Assessment Unit

The Major Hazards Assessment Unit in the HSE has been formed to deal with this work, and also to handle the hazard survey reports that will be produced by companies when the Hazardous Installations Regulations become law. The Unit is currently asked for advice on several hundred planning applications per year. Many of these are difficult to assess and involve considerable technical input - our objective is to give each one proper consideration without unnecessary delay.

FUTURE DIRECTIONS

In the near future I do not foresee any major changes in the U.K. arrangements for siting LEG facilities, but rather a number of initiatives which taken together should improve the quality of decisions made on behalf of the community. I will list these individually:

(i) The Advisory Committee on Major Hazards has recommended that the voluntary arrangements in existence since 1972 should be made statutory. In other words that local planning authorities should be formally required to consult the HSE about every significant planning application in or around hazardous installations before coming to a decision. I think that these recommendations will be implemented and that it will help to ensure a more uniform approach throughout the U.K.

(ii) Then as another aspect of achieving more uniformity and structure some guidelines on the siting of houses, schools etc near major hazard plants would help everyone concerned. The oil, gas and chemical industries would find it helpful to know what the HSE considers to be broadly acceptable separations for the siting of new chemical plant or extensions. A general policy on siting as opposed to advice on individual applications would also help local planning authorities, particularly if such a policy could be incorporated in their structure plans for development before individual planning applications are received and considered.

The Major Hazards Assessment Unit (MHAU) is currently working out a siting policy for LPG installations and in due course this can be extended to cover LEG facilities.

(iii) The HSE is likely to increase its consultation with industry and planning authorities, both on techniques of hazard assessment and on siting issues. Moreover we need to develop our contacts with officials in other countries who are facing the same problems in order to share experience and ideas. The IIASA Task Force Meeting is one very good example of co-operation in this field.

(iv) As a personal view I consider that the U.K. planning enquiry system, which may well be invoked for the siting of at least some future LEG facilities, could be developed and improved. Some constructive ideas on this were contained in an important speech made two years ago by Peter Shore, former Secretary of State for the Environment - a copy is attached as Annex 1. At a humbler level the MHAU can now draw on the experience of two major public enquiries involving LEG facilities.

(v) Such facilities will clearly have an impact on public health and safety, and the operating companies should be encouraged to inform and explain the hazards to the public who are potentially at risk. In this way the risks can be put in context, needless anxiety allayed and sensible neighbourhood planning encouraged. It is likely therefore that regulations will be made under section 3 of the Health and Safety at Work Act requiring companies operating hazardous installations to provide certain prescribed information to the surrounding public who may be affected by their activities. On the same theme of informing and involving the public we will consider the merits of setting up local liaison committees to discuss and develop emergency plans for such sites. There isn't space here to develop fully the ideas listed above but I should be glad to expand on any of them at the Task Force Meeting.

FUTURE DIRECTIONS - OTHER ISSUES

As mentioned earlier the HSE has participated in two public enquiries involving LEG facilities and quite apart from those, has been continually developing its policy as it deals with the safety and siting of major hazard plants generally. In the last part of this paper I will list some of the lessons we have learnt, as they may provide a guide to future directions on the issues of acceptability of risk, public presentation and consultation raised on pages 14 and 15 of the LEG Issues Paper (see Appendix B of this book):

(i) Technical

Siting policies will have to be underpinned by a rigorous technical assessment of the probability and consequences of a major accident. This necessitates detailed consideration, for example, of thermal radiation and blast wave effects, missile damage, vapour cloud dispersion and many other matters.

(ii) Economic

Although we are developing hazard assessment techniques we do not yet attempt full cost benefit analyses. However we recognise that land resources are limited and that it would be quite unrealistic to ignore economic issues in framing siting policies. Consequently our advice is based on a balanced view of the range of foreseeable accidents, not on the worst events which can be imagined. In the U.K. we do not recommend separation distances which ensure absolute safety from the worst conceivable accident; it is accepted that there will almost invariably be some residual risk to people living nearby.

(iii) Role of Industry

Industry has a responsibility to demonstrate to the satisfaction of the HSE and the local community (via their elected representatives on planning committees) that proposed industrial developments will be so designed, operated and sited as not to result in an unacceptable level of risk either to the community or to work-people. One way in which this can be done is by so-called Conceptual Hazard Survey Reports.

(iv) Role of HSE

The MHAU, on behalf of the HSE, will have to assess the hazard survey reports produced by industry but should not do industry's job by taking over the production of those reports. In carrying out these assessments our aim must be to show that we are independent, impartial, technically competent and fully aware of all the different interests of the community.

(v) Action Groups

These are more organised, more articulate and increasingly able to call on expert advice (sometimes from other countries) to support their case. It is essential that the HSE and industry should be prepared to enter into public debate with such groups.

(vi) Public Enquiries

With the greater public awareness of potential hazardous activities, the signs are that public enquiries in relation to proposals for LEG facilities may be more common and certainly more searching than hitherto.

(vii) A pre-enquiry meeting can be very helpful in order to establish areas of agreement and disagreement, as well as to draw up an order of business for the enquiry itself. A preliminary meeting can thus identify the main issues on which the enquiry should concentrate and indicate the documentation which is to be presented.

(viii) Nowadays parties to such enquiries in the U.K. are beginning to expect written technical assessments of the health and safety hazards and any other matters considered to be of prime importance. These assessments are of course best circulated in advance.

(ix) Our experience suggests that such assessments will not be analysed point by point when it comes to the enquiry, but merely probed to determine whether the built-in assumptions are justified, and whether any factor has been overlooked or treated too superficially. Cross-examination will thus undermine or establish the credibility of the assessment, and hence the conclusions drawn from it.

(x) Certain areas of debate are now predictable in relation to LEG facilities (security against terrorism, shipping hazards, acceptability of risk etc). Written submissions on these can be prepared in advance.

(xi) Finally in practice the scope of enquiries as conducted may well exceed the nominal terms of reference and it helps to be well prepared for this.

REFERENCES

1. "Advisory Committee on Major Hazards - First Report", HMSO, London 1976.

2. "Advisory Committee on Major Hazards - Second Report", HMSO, London 1979.

3. Health and Safety Commission, Consultative Document "Hazardous Installations (Notification and Survey) Regulations 1978", HMSO, London 1978.

4. A.C. Barrell, "Assessment of Chemical Plant for the Proposed Hazardous Installations (Notification and Survey) Regulations, Institution of Chemical Engineers, Seventh Symposium on Chemical Process Hazards, Manchester 1980.

5. Health and Safety Executive Report. "Canvey - an investigation of potential hazards from operations in the Canvey Island/Thurrock area." HMSO, London 1978.

ANNEX 1

DEPARTMENT OF THE ENVIRONMENT

PRESS NOTICE 488 13 September 1978

PETER SHORE ON MAJOR PLANNING INQUIRIES

The future role and the significance of major planning inquiries was outlined today by Peter Shore, Secretary of State for the Environment.

Speaking in Manchester, Mr. Shore said:

"I have during the past year given much thought to our system of planning inquiries - particularly as it operates on major and complex issues of which last year's Windscale Inquiry was an outstanding example. But in the period ahead there will be other major planning inquiries, and I want to indicate to you my present thinking about how they can be best handled.

"Perhaps it will help to clarify thinking if I remind you of how in the post-war years we have tended to approach the major important planning cases: those which are sufficiently controversial to come to Ministers for decision. Something like 5000 inquiries are held every year, and of these perhaps a few hundred are highly significant to the locality. But only say two or three a year interest, concern and affect the well-being of us all. It says much, I think, for our planning inquiry system and its procedures, that for the 30 years it has so far existed it has on the whole managed to deal with the whole range and variety of cases in an acceptable and satisfactory manner.

"Let me remind you of the three main principles on which our public inquiry systems has rested. First, that it is for Government and Parliament to determine national policies against which particular proposals are considered at inquiry. These policies - except traditionally in minerals cases - have usually settled such questions as the basic need in national or regional terms for the type of development in question.

"Secondly, against the background of declared national policy there should be, when a planning application has been refused and an appeal has been made, or when a call-in has taken place, a full, scrupulous, impartial and structured inquiry conducted by an Inspector to consider whether there were sufficient reasons for a particular proposal on a particular site, in all the circumstances, to be allowed to proceed or to be turned down.

"Thirdly, in the light of the inquiry and the Inspector's report it is for the Secretary of State under powers specifically granted to him by Parliament in the Town and Country Planning Act to make a decision.

"As I say, in the great majority of important planning cases that come to Ministers, these principles have proved to result - and still do - in decisions that are effective, fair and accepted. Of course there have always been criticisms and that is inevitable because one party is bound to be disappointed and because the procedure, involving as it does a careful and impartial hearing of all the evidence, irritates those who want quick decisions and offends those who are on the losing side who believe that, only if more and more exhaustive studies could be made, their point of view might have prevailed. These criticisms are, I believe, unavoidable but they do not detract from the general utility and value of the system.

"So much for the established features of the system. But in recent times some critical questions have begun to be asked that previously were seldom if ever raised. I will instance three in particular. First, critics have sometimes questioned whether the need for a development has in fact been properly established. And they have claimed that Parliamentary discussion or Ministerial consideration of the first question of the need has often not been sufficiently searching and thorough.

"Secondly, the critics have claimed that certain major proposed developments have implications and repercussions going far beyond the direct impact of the project itself, and these wider effects are not sufficiently considered and that, if they were, the balance between, say national economic considerations and the effect upon the environment and quality of living, could turn out to be very different from that which the developers claim. Consequently critics have argued for a more thorough and disciplined assessment of the total implications of large-scale developments.

"Thirdly, not only the critics but all those engaged in the matter of public scrutiny recognise that there are some development proposals - and I am referring here to major nuclear innovations - that are in a special category of importance and difficulty, not just because they involve technological judgement of great complexity but still more because they can affect our whole way of life and because they involve issues of utmost importance to the safety and health of future generations.

"These are serious concerns and all of them question the traditional approach to public inquiries that I outlined at the beginning of my speech. In short, we must ask the question do we in fact sufficiently establish and define need in certain fields, particularly the energy field, when in the nature of things it is difficult to establish a settled and continuing national policy background before a particular proposal is examined at a public inquiry? Can we in fact take, at a given point in time, sufficient account of all the wide implications of major new ventures as they evolve; and are the techniques that we can employ sufficient to help us with them? Is it right to leave to the Secretary of State, in the vital field of major nuclear innovations which can affect all our future the sole decision - or should Parliament be directly involved?

"Some of the considerations I have been outlining will arise on at least two major energy development proposals which will require Ministerial decisions - the National Coal Board's applications for planning permission for the development of a major new coalfield at Belvoir in North East Leicestershire which have recently been submitted; and the proposals - if and when it comes forward - for a fast breeder nuclear reactor, the CFR 1. May I give you my ideas about the examination of these two very different issues in turn?

"The NCB's applications raise issues of considerable national importance relating to the need for the development of this coalfield, and of course there is the impact such a development would have on an attractive agricultural area. While these issues are initially for consideration by the local planning authority, I intend in due course to call the applications in for public inquiry and my own decision.

"I have been giving serious thought to the most appropriate form of inquiry in this case. It is essential that all the implications of the proposal should be impartially and exhaustively examined. What is the best way of achieving this? One proposal is that we should set up a planning inquiry commission under Section 47 of the Town and Country Planning Act 1971. As you will recall the planning inquiry commission system was introduced into the Planning Acts in the wake of the Roskill Commission on the Third London Airport though it has never been brought into use. It was designed for important proposals which if was felt could not be properly evaluated unless there was a special inquiry, or which involved such unfamiliar technical and scientific aspects that a proper decision could not be arrived at without a special inquiry. However, ten years later we find ourselves in a different situation. At the Windscale Inquiry important changes were made in the scope of the matters open for consideration.

That Inquiry demonstrated how the scope of conventional inquiries could be made much broader. Of course I realise that the conclusions reached by the Inspector were not to everyone's satisfaction. But nobody, I believe, is in doubt that the range of the inquiry was exceptionally wide, with the question of need being exhaustively considered and with the Inspector being specifically asked to examine, for example, the national interest, as well as the rightness of the particular site. It is difficult to argue, therefore, that the planning inquiry commission system is uniquely appropriate now for major inquiries.

"There is however, a further problem with planning inquiry commissions to which I personally do not see a solution. The system envisaged a two-stage procedure, the first being investigatory and the second consisting of one or more public local inquiries. In my view the investigative proceedings are bound to lead the planning inquiry commission to conclusions, by whatever means the proceedings may be conducted. Yet at the second stage, ie at the local inquiry, arguments of policy and principle on which they will already have formed a view are bound to be put to them as well as the more local issues, and I do not think that people will feel that they would get a fair hearing. There is no way round this problem. For all these reasons I am not convinced that a planning inquiry commission is the right way to proceed.

"The planning inquiry I envisage on Belvoir would include questions relating to the need for the proposed development and possibilities for alternative locations, as well as important local economic and environmental implications which I understand have been the subject of a joint study by the County Council and the National Coal Board.

"On the organisation of the inquiry, it is already an increasingly common practice in major inquiries for a preliminary meeting to be held to seek agreement between all those concerned on basic facts and to establish areas of disagreement, as well as to draw up an order of business for the inquiry itself. In the present case I propose to ask the inspector to hold such a preliminary meeting, perhaps extended in scope, to identify the main issues on which he considers the inquiry should concentrate, and to indicate the documentation and further work on implications which he would expect to be presented at the inquiry. I hope that this procedure will enable the time at the inquiry to be used in the most profitable manner and will ensure a full and comprehensive examination of all the issues. I shall be making a further announcement in due course about the arrangements.

"But before I leave the NCB's proposal I would like to mention in connection with it another subject in which there has been general interest - the idea of assessing the environmental impact of significant major developments, as part of the planning process. My colleagues and I have considered how best to pursue this. We fully endorse the desirability, as set out in the Thirlwall/Catlow report, which my Department published in 1976, of ensuring careful evaluation of the possible effects of large developments on the environment. All could agree with that, though we must not forget the unacceptable delays and costs of some environmental assessment procedures used in other countries, nor the strong interest we have as a nation in the success of our industrial strategy.

"The Government has already accepted the recommendations of the Leitch Committee, on the assessment of trunk road scheme for future road inquiries. The approach suggested in Thirlwall/Catlow is already being adopted with many other public and private sector projects. We should therefore wish to encourage use of this approach in cases where its use is worthwhile in the circumstances; relevant to the decision; and necessary to the total evaluation of the project along with the industrial, the employment, the social, the health and safety, the land use and the other implications.

"Our feeling therefore is that in selected major cases, involving environmentally sensitive areas or circumstances, a more explicit approach should be pursued. In the selection of such cases, the initiative could come either from the developer or from the planning authority. We should expect that the planning authorities and the public or private developers would agree at as early a stage as possible whether environmental assessment was justified; and if so the form of, and methods of preparing an assessment, including the division of responsibility for carrying out the work. It would be helpful also if detailed consideration could be given to informing all interested parties including the general public of the scope and nature of the analysis to be undertaken. The sensible use of this approach, through the co-operation of all concerned, should I believe improve the practice in handling these relatively few large and significant development proposals.

"This will take time to bring into effect, but at North East Leicestershire I hope that, if necessary, the important environmental considerations that have already been the subject of a joint study by the County Council and the NCB will be further developed for presentation at the Inquiry, perhaps under guidance from the pre-inquiry meeting.

"In handling Windscale I had in mind two major objectives. The first was that I wanted to ensure as thorough an investigation as I could devise. I needed it for my own purposes as Secretary of State, in order to ensure a fully reasoned and informed decision - a decision that was in all the circumstances and with due allowance for human fallibility - right! It was needed also for the reassurance of public opinion, and indeed world opinion, that a thorough investigation had been made. The second objective was to provide for the involvement of Parliament, for it seemed to me wrong to exclude from a decision of such high national importance - one in which the range and depth of the issues was unique and unparalleled, the elected representative of our people. This of course was achieved. There were in fact two debates in the Commons: a full day's general debate on the Inspector's report, and another on the Special Development Order conferring the permission. For the future, I am in no sense committed to a Windscale type procedure, but the same two objectives in my view apply to nuclear issues of the same complexity and importance.

"As I said, the Windscale Inquiry showed that a planning inquiry could range over a very wide field, so that it could take in major national and international issues, as well as questions of need and of environmental concern. And we were all helped by the Royal Commission's 6th Report on nuclear power which provided an informed and detailed background to nuclear development. But that Inquiry did not settle whether the particular procedures there adopted were the best in all circumstances. I said at the time that this was new territory that we were still working out our ideas, and that if we could devise a better procedure we should do so. So we have been asking ourselves whether, should we be faced with another major proposed development in the nuclear energy field we need an arrangement which builds on some of the elements that went into Windscale, but includes also what I hope will be thought other valuable elements suited to the examination of the project concerned.

"My suggestion, which I hope you and others will turn over in your minds, is this. I have already, in the course of the Windscale Inquiry (and in subsequent House of Commons debates), promised a special procedure for public consultation, a wide-ranging investigation going beyond local considerations and - as with Windscale - I am sure that we must involve Parliament in a decision which has the specially wide-ranging and uncertain repercussions attaching to nuclear projects. What I have in mind, is a first stage public examination, by a suitable body such as a Commission or a Committee, outside the inquiry system to assess the background and the need. The published report of such a body could form a major background document to a subsequent site-specific inquiry. The proposing authority could then be invited to ask the Secretary of State to publish a draft Special Development Order of the kind used for Windscale. This, together with any necessary additional material, would be the subject of a public inquiry with wide terms of reference, held by an inspector and assessors. The report of this inquiry would also be open to public discussion, and the Special Development Order in its final form would be laid before Parliament, becoming subject to debate on a motion to annul.

"To my mind such a procedure would give the most thorough-going investigation possible. In the sophisticated field of nuclear energy it is of the utmost importance to get the answer right. We are a democracy: and we govern by consent. It is our duty to ensure that that consent is justified and to make it possible for the public to feel and to know that the ultimate decisions reached are as wise, fair and acceptable as we are able to make them. This is what we owe to ourselves and that is the responsibility we bear for the future.

DISCUSSION COMMENTS

MACGILL: Just a brief point. It seems to me that the future developments you have outlined are going to involve an enormous increase in the workload. How does that square up with dismal press reports on resources being cut back? Do you consider that your department can cope with what you now set out as your future directions?

BARRELL: I would not be a normal human being if I said we have enough staff to do the task that we are asked to do. But my staff and I have a great interest in our work, and are very highly motivated to do a good job. We always would like more resources, but their allocation is in part a political decision. How much resources should be devoted to the civil service as a whole or to any individual part of it? I think the only thing I can possibly say is that the Health and Safety Executive has been cut back; that is a public fact. It has now been asked to cut back further. That is also publicly known. So far my particular division has not been cut back; in fact, it has been increased slightly over the last 2 or 3 years. Other parts have been cut back substantially. Whether in fact this is sufficient to do the job depends on your point of view. It does mean, of course, that if the workload goes up, we will have to start choosing our priorities more and more carefully.

SINCLAIR: Very briefly—I understood Mr. Locke to say you were not civil servants?

BARRELL: He said he was not a civil servant, but his staff are.

THOMPSON: In the film, people gave the impression that the Health and Safety Executive was a toothless watchdog. You said you had got some fangs. Could you briefly tell us how long they are and how well you use them?

BARRELL: I think our powers are quite considerable. When we drafted the Health and Safety at Work Bill, we put in a number of powers which I think some people expected were going to be cut back when it went through Parliament. But they were not; and hence, they were included in the final Act. I will not describe them in detail but they include such provisions as the powers of entry in certain circumstances to any premises at any time of day or night.

We also have considerable enforcement powers in the law, but we are careful how we use them. We can issue improvement notices, which of course are subject to appeal. We issue some 12,000 improvement notices a year on companies to require them bring in additional safeguards. We issue two or three thousand prohibition notices a year, which in essence require the closing down of part or all of a factory until certain things are corrected. There is an appeal procedure, and it is interesting that we get approximately 90 appeals a year on the total of 15,000 notices, and that the majority of those appeals go our way. So I think on the whole we are probably not issuing notices unnecessarily. Certainly that has usually been the opinion of the courts and tribunal when the matter has been tested. It is a mixture of legal sanctions and the threat of legal sanctions. A lot is achieved by persuasion. Persuasion is the word that we use, but with the threat of prosecution behind it. So the powers are certainly there. There are arguments as to whether we use them sufficiently or not, some people will say we should be even tougher about it, but I believe that we strike a reasonable balance.

CLARENBURG: Mr. Barrell mentioned in his speech, that "one of his objectives is to find methods to deal with the increased workload and to rapidly improve the output of risk assessments." Let me clarify why I picked these points out. In our agency we find that a full risk analyses is a laborious act, one that is done at the expense of a couple of million guilders for a complicated installation. What we try is to arrive at estimates through shortcuts which are perhaps less accurate, but considerably less expensive. Is that what you meant by your comment on improving risk assessments?

BARRELL: We do look for shortcuts. One form of shortcut is to classify hazard plants into categories; for LPG plants within a given size range the assessments are much the same because the technology and the design is much the same. We modify individual cases to take account of any significant departures from the norm. It is certainly a more cost effective approach.

The only other thing to say is in relation to forthcoming legislation. The onus for doing a hazard analysis will be placed on the company. Ms. Macgill mentioned this when she spoke earlier about the responsibility being placed on industry. We consider that those who create the risk must control it. We consider that it is industry's job to manage its risks properly, and to produce the hazard analyses specified under this forthcoming legislation. The important thing that I must add is that these reports are not going to come in and be placed in a cupboard somewhere. They are going to be reviewed critically. There will be a dialogue with the company, in which hopefully, false assumptions, gaps in information, and so on will be detected and discussed. We will obtain whatever additional data is necessary to gain a complete picture.

We do not want to do the initial work ourselves for a variety of reasons. I have already indicated that we consider it is up to the company itself to control the risks. Another reason is that in order to do analyses ourselves we would have to employ far more people. It is better to have those people in industry looking critically at the safety of the plants they manage than in the civil service doing the work at one That is a point of view anyway.

MACGILL: I agree with that point of view but it does not fully answer the question of public accountability. That is what we are trying to raise here.

BARRELL: I am in sympathy with you on that because I think we have to find the means by which hazard analyses can be made more public than they have been in the past. I have suggested one way in which this might be done. We might find ourselves making legislation for that purpose because there are serious problems at the moment about making certain hazard analyses public. There are problems of commercial confidentiality and a number of other things. I am not sure we will progress very far unless we actually have legislation.

LINNEROOTH: I know a little bit about the Major Hazard Committee's attempts to establish some kind of acceptable level of risk. From what I understand they have not done it. I presume that in light of the required hazard assessments, the Health and Safety Executive will find some installations that are not acceptable; and presumably some of them cannot be made acceptable through engineering alone. What will you then do? Can you require the plant to shut down? Can you require them to relocate? Have you ever considered compensation to the people affected?

BARRELL: Yes, we can require them to shut down, but fortunately within a democracy they have the right of appeal against such a decision. We cannot compel them to relocate in the sense that we cannot say "do not go here, go somewhere else," because we do not make planning decisions. That would be a matter for local planning authorities. We can recommend to a planning authority that a plant should not be built on a certain site. If we feel strongly about it, and if the plant is built on the site, we could, if the circumstances warrant it, issue a prohibition notice. We have actually gone a long way down this road in one or two cases. We have not yet come to a point where we have issued a prohibition notice on a plant for these particular reasons, but we have threatened to do so. And it has produced, from our point of view, the right results.

Now as to the subject of giving compensation. It is being discussed increasingly in Britain now. Our agency would not provide the compensation because we are not, in fact, making the planning decision. In law the planning authorities should compensate companies if they have originally been given planning consent and then later have that planning consent in some way restricted. If the planning consent is revoked, it is probably fairly straightforward to get compensation. To my knowledge this has never actually happened. Suppose, however, the planning consent is in some way restricted due to our advice, so the company cannot quite do some of the things it thought it would be able to do on the site. Many people argue this is a case for compensation. However, I do not know of a single case of compensation in the UK so far, in relation to a major hazard site; and no compensation in relation to other plants that might be thought to create some sort of public loss of amenity in respect of safety. There have been one or two cases in relation to smell and noise, but none in relation to public safety.

CAMPBELL: There are methods of compensation within the planning system which can take account of the limitations on development imposed by a major hazard. A person who is not allowed to put up a house near an explosive plant may, in certain circumstances, be compensated.

OTWAY: I have two observations on Mr. Barrell's paper. I was interested to hear of your providing the public with more information. This is a commendable objective, but people are extremely sensitive to the type of information provided and the way in which it is provided. There are examples of provided information having paradoxical effects--exactly the opposite of what was expected. It is important to study these effects so one can learn how "not to do it".

Another comment regards your wanting to have industry do the analyses, with your agency critically examining their analyses. I think that acquiring a scientific discipline restricts the way one is able to view the world. You are likely to have a view of things which has been shaped by the discipline which you have studied. I am not very much convinced by, say, civil engineers critically reviewing work of other civil engineers, because I think they are more or less the same person even though they represent different interests.

BARRELL: I agree with the point made by Harry Otway that information to the public does not always achieve the expected result. We already have some experience of that actually happening. Usually when you give more information you, in fact, arouse more controversy not less. But nevertheless I think it is something we should aim to do.

I accept Otway's point about specialist reports being looked at by other specialists who have the same blinkers on. We are very aware of that in my unit and one of the first things I told my staff when they joined me was that they were no longer simply psychologists, economists, or civil, mechanical, electrical and chemical engineers. They must develop a multidisciplinary approach, a broad approach, in examining hazard analyses. Whether we have in fact achieved that remains to be seen. It is a real danger, as you say, that one can make the same mistakes when looking at a report that the originators of the report made. I do believe that there are severe difficulties in carrying out detailed assessments in advance of commencement of a major project.

J. SCHWARZ: You have pointed out some recommendations for the future. I think basically they are right, but I have some doubts about the problems you will meet when you want to try to put this into practice. Let me point to the LPG case in the Netherlands, where the decision is taken prior to the rigorous technical assessments you requested are completed. You have the problem of the multi-nationals saying "if you do not settle this in quite a short time then we are going elsewhere." Policy makers then seem to be a little bit anxious about waiting for comprehensive, time-consuming risk analyses.

BARRELL: We are already in a situation where approximately 50 cases a month are being referred to us for advice. When a company provide us a with hazard analysis, we do not accept everything they put forward. We have our own access to expert scientific opinion both within the HSE and outside the HSE and we are guided by what we believe is the consensus of current thinking in the research field on such matters as gas cloud dispersion. If a survey report comes in which does not satisfy us, then we will send it back to be reviewed. I am not theorizing about this. This actually happens.

DALL: You used a rather interesting phrase in your presentation--"the confidentiality of the hazard." It seems to be burdened with an assumption that individual projects that you consider and on which you consult have unique hazards. Our experience in the U.S has been that we can generalize very readily so that there is nothing proprietary about hazards. Everyone uses the same pipes, and the same valves, etc. So what do you mean by this phrase?

SALZ: I think within the Netherlands as well as in the Federal Republic of Germany, there is almost the same system of law. As far as I know there are several kinds of confidential analyses which are present in this case. There are analyses which must be undertaken by the firm, and presented to licensing authority. There are other analyses which should be given to the public in advance of some hearing or something else.

BARRELL: With respect to "confidentiality of hazards"--I was not aware that I used it in quite those words. What I was striving to say was that there are problems of commercial confidentiality which inhibit the release, in full, of some of the material that we get from companies. In writing a really good and thorough hazard report, if you put it all into one report, you almost inevitably include material which is of some commercial confidentiality, and sometimes there are security aspects involved. We are now encouraging companies to produce reports which have these commercial aspects removed from them so that the report which remains can be published *in toto*. I personally think it is possible to do that, because, like you, I think that the sources of hazard are often common between many plants. The other information on the commercially confidential details of processes can be provided just to us. We need this total information because we have to question whether, in fact, there are other hazards in those processes that have not been identified by the company.

DALL: If I wanted my engineers to look at the hazard analysis in an LPG facility in Scotland, would you be prepared to circulate the necessary detailed drawings so my engineers could actually look at it? If not, why?

BARRELL: Not the detailed drawings, because they may be commercially confidential.

DALL: It is also the public health and safety that is at stake. You are engaged in a very interesting tradeoff, it seems. On the one hand protecting the proprietary rights of industry, and on the other hand making some adjustments against the public health and welfare, which could have traumatic consequences.

BARRELL: Yes, there is a line to be drawn there. What I am quite clear about is that in the UK I doubt if we could ever get in a position where all drawings and all process details are made public by a company before it even starts operation. There is not a well defined line to be drawn between releasing all the material and releasing none at all. I am in favor of releasing more, however, it may not be possible to release the document, if you have put all the hazard and commercial information in together. I think it is going to be necessary to separate the two elements.

DALL: What this means, then, is that the public is effectively, in very important areas, excluded from substantive comment.

BARRELL: To a degree that may be correct, but I am saying that the hazard information should be open to scrutiny.

BULL: I would like to make a comment which I have labeled "management systems and people." It seems to me that a number of serious major incidents in the field of large technology have pointed out some classic and rather simple blunders. These blunders can be ascribed to faults in management systems as they exist. Risk analyses assumes everything about the potential. But the most important weak link in the chain is not always best addressed. It is diplomatically a very difficult problem to address. We all think we are good drivers round this table—some of us are excellent and some of us could only just pass the test. Have you tackled with this problem, especially in existing installations?

BARRELL: I think that David Bull's point is a very important one concerning management systems and people. I have to think that the hardware aspects of major hazard plants are considerably overemphasized, because it is much easier to write about them than it is to write about management systems. It is towards management systems that we should direct more of our energies in the future. We are endeavoring to do this. It is difficult, of course, to assess management competence and, what is more, it is a very sensitive issue. The techniques have not yet been developed very well, in my opinion. Not enough work has been done in this field.

MEHTA: I would like to support Mr. Barrell, in what he says about his concern for the need for siting guidelines, and separation of major hazard plants. We will certainly find that very useful, and it will certainly help to avoid the anomalies we have seen in the past, such as the one mile separation zone being implied at PeterHead and to some extent Mossmorran. Half a mile is unacceptable in the Midlands where there is stored 1200 tons of butane. Yet half a mile is being considered acceptable at Braefoot Bay with more than 15000 tons of ethylene. Certainly we would avoid such anomalies if we were all clear on the siting criteria being applied. The inquiry into the 1974 Flixborough disaster, has produced a recommendation that there should be at least a one mile separation zone between major hazard industries and populations.

Secondly, Mr. Barrell mentioned a question of the competitiveness of industry. I would like to suggest to him that matters such as whether industry is competitive should really be left to the businessmen and politicians. The function of his organization should be to be concerned purely on technical matters of safety. Otherwise there is a great danger of safety being compromised.

He quite correctly pointed out that the Health and Safety Executive does have legal powers of enforcement although I have yet to see any of that being done in a major hazard installation. This is further explained by the structure of the organization. The Health and Safety Commission as a policy making body, is composed partly of representatives--three from industry, three from labor and three others. In an organization like that it is almost inevitable that industry is the dominating force. In fact then, there is this great danger of industry regulating or trying to regulate itself. We should find some way to operate an independent unit which is not greatly influenced by industry.

BARRELL: I agree with Mr. Mehta that matters of national economics should be left to the politicians. I would suggest that that is, in fact, what happened at Mossmorran. The decision was taken by the Secretary of State.

He mentioned his doubts about how real our teeth are. It is a bit difficult to give examples of this in relation to Mossmorran, while we are still discussing the details of its design and operation. But have no doubt that we intend to ensure that it complies fully with the health and safety law. I cannot say more than that.

CAMPBELL: To take an example of what you [Barrell] are referring to, there is a school which was partly built, but where building work has now stopped because of action you have taken.

BARRELL: That case could be discussed more openly because it has been resolved.

RAVETZ: I would first like to clarify something that I said at Monday's session which might have given some false impressions of what I was trying to say. I did speak in a somewhat provocative manner. The point I want to make is that I was not claiming that all administrators are simultaneously incompetent or tyrannical. What I was saying, was if we wish to understand how a process is to be well run we must face and study some of the pathologies. I think people in medical science would agree with that.

I do have one direct question for Tony [Barrell]. When you have people in a firm doing risk assessments or risk hazard analysis, how do they learn how to do it? Is there any book to which one can go, giving you standard examples and accepted techniques?

BARRELL: No, there are no really good books on the subject. The field is open for anyone who wants to write one. There are certain texts which you can use, which go part of the way. They include the description of the so-called Hazop techniques--Hazards and Operability Techniques--of assessment. This is an approach developed by ICI, and published by the British Chemical Industries Association. The hazard analyses that we have had so far from major companies are not nearly as good as they should be. Everybody is at the beginning of a very lengthy learning stage.

RAVETZ: I will comment now on something which was implicit in what Tony said but did not come out in a very systematic way. What strikes me, is the way in which one is living and thinking in an extended time scale. One is responsible for messes that occurred in the past, which may or may not be capable of being sorted out. One is responsible for handling things which are unsatisfactory but practically not changed from the past. One is living in the present, acting in the present, yet planning for future activities, standards and criteria that are different qualitatively and quantitatively from those existing today. So, although the present is never satisfactory and the past is even worse, one is always looking forward to a better future, at least in this field.

This is not something inevitable to the human condition, but from the evidence I have about the UK, and it seems to be copied all over Europe, there has been a quiet, but very real transformation of official attitudes in the field of hazards within the last 10 or 15 years. I think this started with health and safety at work, which in England, was in a particularly deplorable state up until recently. Then you had Royal Commissions out of which came legislation which was rather permissive in many respects. These commissions produced administration which becomes more bold and self-confident, as the years go by. So I feel we are now catching up with one of the important areas of high technology society, a recognition that the quality of life is not measured merely in terms of television sets and clear air, but also in terms of reduction of hazards, particularly at work. So everything is changing very quickly. Criticisms of concepts like "acceptable risk" can sometimes miss the mark simply because they are on the wrong part of the timetrack. What is acceptable depends on context, which is related to its evolutionary time and location in history. This makes thinking about risks a lot more complicated and a lot more interesting than thinking about most scientific and engineering problems.

I want to talk now about the politics of risks. I was told personally by Walt Patterson, from the Friends of Earth, that they were able to leap into the great nuclear debate of 1974, because the British General Electric made a deal with the French nuclear people that we must have something like 45 reactors built between us within the next 10-15 years, otherwise disaster. Fortunately, they wanted the American PWR, on which technical material was available. So London Friends of Earth called up New York and obtained hundred-weights of documents, so they could argue about the reactor design. If General Electric had gone to the British designed Advanced Gas Reactor, which might have developed other problems, London Friends of Earth would have had nothing to say because they would have no information on this technology.

Knowledge can be power-- commercial power, political power. So there is never a totally clean or innocent request for knowledge even about hazards. This, of course, brings one to the question of participation in risk discussion. It is highly unlikely that in the UK someone could actually make a living by consulting to environmental or intervenor groups. This vast difference in government style exists between the U.S. and the UK. Because of the way the legislation, lobbying, and litigation is done, there is in America a large industry of certain type of experts who get "standing" in the process. In the UK, even though there will be consultation of a sort, there is certainly no tradition for the according of standing in the process to anyone who is not part of the existing decision structure. Thus, civil servants, in various ways, will consult with industrial associations, local authorities, and established trade unions; but with special interest groups, no. I think we have seen an extreme case of this, in the case of the Mossmorran group. There is no place for them in the system, except when, in the form of an inquiry, they are briefly brought in. In California the politics of hazards are entirely different.

It is encouraging to know that people in the Health and Safety Executive are coming around. A consensus is moving to the view that disasters are essentially man-made. This was brought out very effectively in a course unit on man-made disasters at the Open University. The thesis put forward is that disasters do not occur by a concatination of random events. They occur because systems designed to prevent the incidents from occurring, actually fail.

It is not merely a question of embarrassing management, it is a question of the change of practices of attitudes that would be required to actually prevent disasters. As an example, consider the history of neighbors complaining about emissions or incidents. In the past the company, the local authorities, and the inspectors always dismissed these complaints.

A case occurred concerning a whole lot of coal and rubbish, which was tipped on top of a valley; and due to water leakage, one of this tips became unstable. It went right down the side of the hill and engulfed a school killing around 135 children. In the inquiry afterwards it became clear that people had been complaining about the tip, had been complaining about the dangers, complaining about the water, complaining about everything, and they had been getting the runaround. The reason why was that every person to whom they complained had a responsibility other than the safety of the city.

This disaster reminded me of Mossmorran. Suppose that after the installation people began noticing funny puffs of smoke, or funny rumbles, or people with binoculars watch those boats go around the reefs and they keep a log and start complaining. The question is, "would their complaints have any standing?" As the situation stands now, my feeling is "None whatsoever." They would have to accumulate these complaints and then have another scaremongering program on television. It is possible that quietly the Health and Safety Executive would take cognizance of their work, but certainly, as tradition stands at the moment, there would be no possibility of them being given standing as valid, bonafide, useful observers in the safety and inspection process.

I have one major point to make that sums up my thoughts. In all the countries you have three major considerations--rules, style of power, and style of negotiation. I know two countries reasonably well in this context--the US and the UK. The rules in the U.S. tend to be formalistic and encyclopedic. The style of negotiation is "litigous"--one litigates all the time. The legal experts who are brought in also are distrusted just like lawyers are distrusted; however, you cannot do without them. This comes from a long tradition of participatory style/distribution of power where there is a very weak central government relative to non-government institutions. There is a safeguard in the system called "Due Process" which enables you to take any complaint to the courts.

Now in the UK the rules are generally informal and as Mike Thompson said they are iterative in that you work them out as you proceed. Even though you had no idea what the rules meant in the beginning, after a year or so you could certainly interpret them from case to case. The style of power is paternalistic, and a quick word for its origins is "squirearchy". Then the style of negotiations will be consensual, but with very controlled consultation. In other words, only certain people have access to a consultation. I saw this vividly when in 1977 I came back from three months in the states where I had watched the great DNA debate, which was wild and vicious and insulting and brutal *and open*, and then came back and went to my first meeting at GMAG, which was beautiful, very sensible, very responsible, and behind closed doors. In Britain the safeguard seems to be a sense of fairplay, which leaves rather less redress for someone who has been victimized by someone playing unfairly; because there is no constitutional machinery for protection.

The French seems to have the same sort of informal type of rule. The style of power clearly is elitist, depending on the experts. There is a long tradition of the country being run very centrally by bureaucrats on behalf of democracy. The style of negotiation is consensual and private. There is a copy of application in every town near the plant, and any citizen may comment on it. These ideas may be taken into account but they are only considered privately by the different expert groups. I do not know if there is a safeguard in the system against either bad decisions or bad administrations. But as Mr. Vincent has stated, everyone does have a right of appeal.

My last point relates to awareness. There are certain levels at which acts are performed, certain levels of awareness--public, semi-private, private. Certainly there is no denying that a complex game is being played where power is one of the elements of the game. I do believe it is fair to say that Mr. Campbell's description is of an endeavor where considerations of power are not there. He described a planning system where basically it is just finding the ethically best solution to the problem.

I would like to relate a story in which I think illustrates how cultures can be very different even separated by a channel. At a conference I attended two weeks ago we were discussing the process of safety regulations as they are influenced by nonsafety considerations and someone gave an example of how these things can be manipulated. The illustration was that of fork lift trucks, where, obviously, the design of the fuel tank is very important. Someone said, "Ha, Ha, the reason regulations coming out of France are so designed is so that only French manufactured fork lift trucks can pass these regulations." Then a junior minister, Timothy Sainsbury, from Great Britain, gets really upset and says "That cannot be. That is a non-tariff barrier to trade. Now I know that sometimes this happens, but you *cannot* have that happening within the European Economic Community, because there is a treaty which makes that illegal." So you do have very deep differences between the British and French attitudes toward certain problems which I think are important aspects of the way in which the hazards game is played.

REIJNDERS: I do not agree with the conclusion that things will get better now. I believe that increasing technological problems will outrun improvements in the attitude of the officials. I do not see a real net improvement in the situation.

RAVETZ: With the possible exception of the accumulated industrial waste and pollution, I think, generally speaking, at least on this side of the ocean, we are improving on physical hazards.

REIJNDERS: The introduction of large-scale systems is almost the same everywhere, with some minor differences in details, conceptions, etc. But we all have the same problems, and we all are running into the same type of hazards, and I ask myself "Why is it?"

RAVETZ: All I can say is this, that in the advanced countries we share a same basic technology. There may be a few stylistic differences. On the other hand, the way we respond to the problem depends on our human traits. What we are finding here is that the material culture does not tightly determine the superstructure of ideas, habits, expectations. When it comes to the construction of the very sensitive and delicate instruments for controlling that technology, they will differ between countries because they must fit into a different constitutional framework. And there is a paradox here.

J. SCHWARZ: I think the problem is that if we want to understand the problems we face in these fields of hazards, then I have the impression that only the styles differ. The outcomes and the results between countries, in my opinion, are highly similar. And I see a lot of similarities in the Dutch problem, although the cultural differences are quite distinct.

MEHTA: We must appreciate the contrast between the British system with those in France, the USA or the Netherlands. In Britain we lack the checks and balances, especially the right of appeal against decisions on planning, or control of technology. In fact, we have no written constitution and no bill of rights, I think what we have in the UK, is the worst of all that we have been looking at. I would not award the award of "fairplay" to the UK as Ravetz has done.

RAVETZ: "Fairplay" is the only safeguard and if you get *unfair* play then you have nothing at all. That is what I really feel has happened in your case.

IV. ANALYSES IN THE SITING PROCESS

The papers in this section address, for the most part, the broad methodological issues concerning the role of analyses in the LEG siting process. In addition, two of the papers (Lathrop and Schwarz) illustrate the application of such analytical techniques to specific case studies.

Analysts are interested in the siting of large-scale facilities in terms of the role played by technical, economic, and, especially here, risk analyses. Prescriptive siting analyses can be made broad enough, it is suggested, to include the important societal concerns and the value trade-offs involved. However, numerous interviews with the participants in LEG facility siting processes have shown that technical, economic, and risk analyses often do not play a clear, unambiguous central role. The actual process is often best described as political and not particularly sensitive to the results of analyses as they are presented. The role of analyses is often subtle, and hard to identify in the midst of a decision process with several interested parties.

Acknowledging, then, the political nature of the process, a study of the role of analyses seems appropriate. The particular focus of the present research is the role risk analyses play in facility siting: (1) how the analyses are done, and (2) what improvements could be made accounting for differences between nations. The following papers and discussions provide a framework for expanding and improving the use of analyses in the siting process and decision making.

Ralph L. Keeney's paper deals with the use of decision analysis in the facility siting process. The solution or resolution of the LEG siting problem is dealt with by Jerry R. Ravetz. The paper by John W. Lathrop is concerned with the role of risk assessment in facility siting. Jaap J. Schwarz presents the energy policy situation in the Netherlands Finally, there is the edited presentation of Michael Thompson who discusses the socio-anthropological styles of LEG siting between the various countries.

SITING ENERGY FACILITIES USING DECISION ANALYSIS *

Ralph L. Keeney
Woodward-Clyde Consultants

1. The Siting Problem

During the next several years, hundreds of corporations, utilities, and government agencies will construct a large number of major energy facilities. These include power plants, dams, refineries, import terminals, storage facilities, waste disposal facilities, mines, pipelines, and transmission lines which are critical to our quality of life. Appropriate sites must be found for these facilities. Because the stakes and potential consequences of any particular siting decision are large, it is worthwhile to conduct a formal analysis to aid the professional intuition of the decision makers with responsibilities for selecting such sites. Without excessive costs or effort, an analysis can be responsive to the needs of these decision makers.

There are a number of characteristics which render it worthwhile to conduct an analysis of a siting problem. A formal study would be justified by any of the following:

High stakes. The difference in desirability between sites can be enormous: for example, hundreds of millions of dollars or severe local environmental damage.

* Acknowlegement. The work described here is supported in part by the Office of Naval Research with contract N0014-78-C-0688. The paper is adapted from Keeney [1980].

Complicated structure. Multiple objectives, uncertainties, and values are some of the features contributing to the complexity inherent in most siting problems. This makes it very difficult to appraise informally each of the alternative sites in any particular case.

No overall experts. Because of the breadth of concerns in siting problems, there are no overall experts. Different individuals are, however, experts in relevant disciplines such as economics, engineering, and the various branches of science.

Need to justify decisions. In order to ensure that the public interest is accounted for in siting decisions, petitioners who wish to build energy facilities must justify their proposed actions to obtain authorization from regulatory agencies.

Collectively, these characteristics describe a very involved problem. Yet, there is no doubt that siting decisions will continue to be made. One might argue that the problems are so involved that formal analysis cannot be expected to solve the problem. I agree. Formal analysis will not solve the problem, nor is it intended to do that. It is intended to help decision makers make responsible decisions. It is precisely the complexity which implies that a formal analysis should be done.

There are two basic goals of a formal analysis of siting problems. The first is to reduce the likelihood of a poor outcome (or increase the likelihood of a good outcome) or, more precisely, to improve the quality of the decision taken. This goal is worthwhile because of the high stakes and is difficult to accomplish because of the complicated structure.

By improving the quality of the decision, we mean to include several things. The analysis should stimulate constructive discussion and provide a framework for identifying and resolving conflicts. It should produce insights which may not be obvious because of the complex nature of the problem. An explicit analysis makes it easier to track completely and logically all that is relevant. Because there are no overall experts, one of the most important functions of analysis is to provide a framework for integrating the information from the diverse disciplines working on different aspects of the siting problem. In some sense, the model plays the role of the nonexistent overall expert, and yet it is just a useful tool of the decision makers, analysts, regulators, and various experts who are interested in the siting problem.

The second goal of a formal siting study is to provide a rationale and documentation for supporting the siting decision before regulatory authorities, as well as sometimes before shareholders and the public. It should not only indicate what information was collected from where, but how it was used and why it implied the proposed site was the best of the alternatives. The model is also a device which can answer "what if" questions often posed by regulatory bodies.

In order to achieve the two stated goals, the analysis of a siting problem must be thorough and competent. Thorough means that the complexity of the siting problem needs to be considered. Competent refers to both the depth and completeness with which this complexity is analyzed and the logic which is used to integrate the parts of the analysis. The analysis needs to be theoretically sound and practical. The decision analysis siting approach uniquely meets these requirements.

2. The Client for Siting Analyses

The main purpose of siting analyses is to help a decision maker select a site for a proposed facility. This is very different from describing the procedure by which a site will be chosen for that same proposed facility. The former concerns what is referred to as prescriptive decision analysis--helping to decide what should be done. The latter concerns descriptive decision studies--trying to describe what will be done. This prescriptive orientation has major implications for the role of, and in fact the existence of, a "decision maker" in the siting problem.

Clearly, there are many decision makers in major energy siting problems. Our purpose is to prescribe how one of these decision makers or perhaps more than one should act--which decisions they should make and why--if they wish to behave responsibly and consistently in such a complex decision environment. To define our terms, a client will refer to any decision maker for whom an analysis is conducted in order to aid the client's decision making process. Clients may be companies, governmental agencies, or other interested parties. Each client has a decision to make which may or may not depend on what the other decision makers in the process do. For instance, the selection by a utility company of a site for a coal power plant may depend on perceived reactions (decisions) of environmental and local interest groups with respect to the alternative sites.

From a prescriptive perspective, the most common siting problem is that of a single client. Our major concern is with the client who is searching for the best site, or at least a very good one, to locate a major facility. Examples are a utility company finding a site for a power plant, an oil company finding a site for a refinery, and a segment of the government finding a site for the storage of oil or for nuclear waste disposal. Such a client has the responsibility for the major siting decision in choosing among the many possible sites available. Other decision makers only decide whether the client's chosen site is satisfactory.

For the single-client problem, both the judgments of impacts and evaluation of the impacts will be provided by the client or other designated parties. The impact data will necessarily come from a host of disciplines, including economics, meteorology, seismology, water resources, environmental sciences, and medical fields. One might expect that a good analysis would uncover the true information about the likely impacts at each of the various sites and, hence, there would be substantial agreement among various experts about the potential impacts. On the other hand, there are no true values. There could be a large disparity between the client's values and others in society. In fact, the reason for regulatory processes is to ensure that the actions taken by those being regulated do not conflict with general values of society. Thus, the client would normally take the perceived values of society into account when establishing his or her values for siting. For instance, because of the increased environmental consciousness of society, utility companies, oil companies, and the government each places a higher value on environmental impacts than they did a decade ago.

Sometimes the major siting decision is the responsibility of a consortium of clients. Examples include a regional power pool (i.e., group of utility companies) selecting a power plant site, two government agencies selecting a hydroelectric dam site for multiple purposes, and the government and several oil companies selecting a site for a deep-water port for oil imports.

The multiple clients may use the same groups of individuals to collect and process the information about impacts at each site. This aspect of the problem would not be so different from the single-client version. Given this information, all the clients may be in reasonable agreement about the possible impacts. However, the clients may not be in agreement about the appropriate value structure for evaluating these impacts. If, indeed, the different value structures imply that different sites are better than others, the conflict must be resolved before proceeding. The unique feature of the multiple-client problem, which makes it different from the single-client problem, is the requirement for resolving such conflicts. Value judgments are again needed to decide how to resolve conflicts which persist after careful scrutiny.

3. A Framework for Siting Analyses

The essence of the energy siting problem is illustrated in Figure 1. The first requirement of the siting analysis is to determine specific candidate sites to be utilized in the analysis and specific siting objectives appropriate for the problem. Then each of the sites must be

		Siting Objectives			
		1	2	. . .	N
	Site 1	Impact of site 1 with respect to objective 1	Impact of site 1 with respect to objective 2	. . .	Impact of site 1 with respect to objective N
Alternative Candidate Sites	Site 2	Impact of site 2 with respect to objective 1	Impact of site 2 with respect to objective 2	. . .	Impact of site 2 with respect to objective N
	.	.	.		.
	.	.	.		.
	.	.	.		.
	Site J	Impact of site J with respect to objective 1	Impact of site J with respect to objective 2	. . .	Impact of site J with respect to objective N

Figure 1. A Framework for Energy Siting Analyses

appraised in terms of the impact they would have with respect to each of the objectives. The next step is to evaluate all the various impacts for each site and combine these impacts to determine some "overall value" for each site. These overall values are then compared with each other to lend insight about the best site for a specific problem.

Although the siting problem is simple conceptually, it is often very difficult in practice for a number of reasons. First, the candidate sites are often not known at the time it is recognized that a siting problem exists. Second, it is not clear what the objectives for the specific study should be. Both the identification of candidate sites and the specification of siting objectives require substantial creative input from numerous disciplines involved in siting as well as the decision makers for the problem. Even once the sites and objectives are determined, there are numerous difficulties in clarifying the impacts of each of the sites. Finally, the value judgments necessary to evaluate and integrate the impacts of each site are also difficult, though necessary, to make. The decision analysis siting approach addresses each of the major complexities illustrated by Figure 1 directly and explicitly. Before outlining the steps of such an analysis, let us limit the scope of the siting problem and elaborate the features which render siting problems so complex.

Limiting the Problem Scope

The general rule for deciding if a consideration should be included in evaluating alternative sites is whether or not that inclusion could have a significant impact on the site evaluations. As an example, if the cost of acquiring land for all candidate sites was equivalent, this could be omitted in a comparative consideration. However, such a consideration may be relevant in deciding whether or not to use any site. This general rule allows us to eliminate many considerations from siting studies.

For many siting problems, it is reasonable to assume that the benefits of the proposed project will be essentially the same for each of the alternatives. The electricity generated from a 1000 MWe power plant will probably have the same benefits regardless of where it is located within a region. This is not precisely true since line losses may be different for the various sites. However, if such differences are felt to be important, the losses could just be considered as one of the disadvantages of a particular location.

There are many important energy decisions made at a national level that are almost irrelevant to siting decisions. As an example, the decision about how much capacity to supply clearly affects how many facilities will be built. But in the decision to build a specific facility, the evaluation of which site is best does not depend strongly on the number of facilities being built elsewhere. Other national (or international) issues which seem to have little effect on siting include the deregulation of natural gas prices, an oil embargo, or possible legislation curtailing operations of fossil fuel power plants because of the "greenhouse effect."

In many situations, aspects of the fuel cycle do not need to be considered in comparing sites. If one is considering using coal from a particular source as fuel for a coal-fired power plant, the impacts of mining the coal will probably be identical for each of the possible sites. Furthermore, transportation of the fuel in certain cases is almost site independent. By this it is meant that differences are small enough to neglect. Such fuel acquisition and transportation impacts for either nuclear power plants or liquid natural gas import terminals need not be considered if they are located within a few hundred miles of each other.

Many operation and maintenance costs do not depend on the site. If proposed facilities are essentially identical and if maintenance is an activity which occurs mainly indoors, such an assumption seems reasonable. This would be true to a large degree with facilities such as liquefaction plants, fuel storage centers, and base-load power plants, such as nuclear, coal, or solar. For hydroelectric or geothermal power plants, offshore facilities, or pipelines and power lines, the appropriateness of eliminating the economic costs of operation and maintenance probably needs to be considered on a case-specific basis.

Given the boundaries of the siting problem discussed above, it may be possible to conclude that our general problem is rather limited in scope and relevant only after all the policy decisions have been made. That is, only after one has decided to build a facility, when it should be built, what capacity it should have, and what fuel to use, does one get to the siting problem. This view is not true. Because of the interdependent nature of all these questions, it may be best in many circumstances to first conduct a siting study to provide crucial information for the other policy decisions.

To the extent that one feels that sites of about "equal value" are available for anything one decides to build, these policy decisions can be addressed before finding a site. In such a policy analysis, one assumes that a site will be found which has a high enough value to make the policy decision legitimate. However, as public priorities have changed in the last few decades, the number of potentially adequate sites for large-scale facilities has been significantly reduced. This phenomenon is mainly a result of increasing emphasis on environmental quality. The assumption that good sites can always be found is rapidly becoming less appropriate. This means that siting decisions should increasingly become a fundamental component in many policy decisions regarding energy.

4. Features Complicating the Siting Problem

No one who has thought about siting problems thinks they are simple. On the other hand, perhaps one should just look for a site which measures up as much as possible in terms of the siting objectives and then select it. That doesn't sound too difficult. However, that is essentially what we do propose, and it is extremely difficult. In this section, we shall discuss a host of features which complicate the siting problem.

These features render it very difficult to determine how well a particular site does, in fact, measure up to what is desired.

Numerous Possible Sites. At the origin of the study, the client often feels that the site may be located anywhere in a loosely-defined, relatively large region of interest. For example, an oil company or LNG company may have 1000 kilometers of coast as a region of interest for an import terminal and conversion facility.

Within any region of interest, there are often literally hundreds of potential sites for energy facilities. This can be recognized just by comparing the area needed for the facility, usually on the order of a few square kilometers, to the area of the region of interest. Many--in fact, most--of these potential sites are inappropriate for a variety of reasons. Some can easily be eliminated from consideration. Often, however, after the easy cases are eliminated, there are still too many potential sites to evaluate thoroughly. One must reduce the number of potential sites to a manageable group of candidate sites, which will then be carefully compared with each other. This process requires the balancing of the time and effort required for the task against the likelihood that more cursory procedures may inadvertently eliminate some or all of the best sites. It is not an easy balancing act to do.

Multiple Objectives. In every siting problem, we should expect that there would be multiple objectives. Some would indicate economic concerns, some environmental, some health and safety, and so on. The overall desirability depends on the possible impact with respect to each of these.

Several Interest Groups. For many siting problems, the client may be concerned with the impacts of the proposed facility on several groups of individuals. External to the client organization, these groups may include the consumers of the product, business interests, citizens in communities which may be impacted by the proposed sites, organizations of environmentalists or sports enthusiasts, and heritage committees.

Within the client company, there may be groups with different opinions, for example, company management, shareholders, and employees who will work at the proposed facility. Such information would not only be relevant to decisions about the appropriateness of a particular site, but it might suggest measures which could be used to improve a particular site.

Intangibles. Many of the objectives in a siting problem will involve intangible factors. By this we mean factors for which there is no obvious way to measure the impact. An example is the aesthetic impact of a transmission line that obscures the view of an otherwise natural mountain scene. Another is the social disruption that individuals in a community may feel as a result of the rapid influx of construction workers. Psychological and moral considerations such as the fear of living downstream from a dam or the question of whether a company should be able to build facilities on native lands are also representative of the intangible aspects of siting problems. In many problems, the morale of the workers at a proposed facility is an intangible factor which requires careful consideration in the siting decision.

Degree of Impact. For each proposed site and each objective, it is not enough to state that there will or will not be some impact. It probably will be necessary, as well as informative, to indicate the degree of impact that might be expected. The issue is not if there is an impact but rather how much impact and how important it is. Thus, a scale is needed for measuring each of the objectives.

Long Time Horizons. The impacts of interest in most siting studies do not all occur at the same time. Furthermore, many impacts, such as pollution, continue over the lifetime of the project. The time horizon is of interest because the value of a particular impact may depend strongly on when it occurs as well as what it is. This phenomenon is well understood with economic concerns. It is more or less universally agreed that a cost of 5 million dollars tomorrow is less than a cost of 5 million in two years. One method which is consistent with such a preference for money is discounting at a fixed rate. However, discounting implicitly makes many other assumptions which may not be appropriate for examining energy investments.

Uncertainties about Impacts. Unfortunately, it is simply impossible to forecast all of the impacts for any proposed energy facility at any site. There may be large uncertainties about the possible environmental impacts, all future costs, the likelihood of accidents, and the impacts of such accidents. The major reasons for the existence and persistence of these uncertainties are:

1. little or no data can be gathered for some events,
2. some data are very expensive or time consuming to obtain,
3. natural phenomena such as earthquakes and droughts affect impacts,
4. people move, affecting future impacts,
5. priorities, and hence, perceived impacts, change over time, and
6. it is impossible to forecast the future completely.

There is no field investigation or research program which can completely eliminate all of the uncertainties, and yet their resolution may be critical to the final implications of the various siting options. It is, therefore, prudent to acknowledge and explicitly consider the uncertainties in appraising the site options.

Time Delays in Licensing and Construction. There are several possible causes of delay in getting an energy facility into operation. Such delays, which can occur in either the licensing or construction phase of a proposed facility, can have a significant impact on the economic viability of the project. Site-dependent delays, such as one due to a court suit over the license to cross a particular piece of land with transmission facilities, may be necessary for the site comparison.

Operating Reliability. Many types of energy facilities have scheduled maintenance which requires that the operations of the facility be curtailed or stopped for a certain time period. Because of the planning for these, one expects the time involved to be essentially the same for similar facilities. However, the circumstances which may force unscheduled shutdown or curtailment of the facilities' operations may depend strongly on the site. The main causes for such differences would be natural phenomena, such as severe storms, and accessibility to allow continuing operations or correcting any problems.

Value Tradeoffs. As indicated, most siting problems involve multiple objectives. If it were possible, the client would clearly prefer to optimize with respect to each of these objectives simultaneously. Realistically this simply cannot be done. Value tradeoffs between objectives are inevitably part of siting problems. One can address this feature either formally or informally. However, the possibility of ignoring value tradeoffs and hoping they will go away just does not exist.

Equity. It would be nice to satisfy each of the groups interested in a particular siting problem. However, value tradeoffs will have to be made because the lot of some groups can only be improved at the expense of others, once dominated alternatives are eliminated from further consideration. However, there is a special consideration necessary when determining the value tradeoffs between groups, that is, equity. It is important to be as fair as possible for each group. Determining what is fair is often a very difficult task involving complex value judgments.

Risk Attitudes. Because of the uncertainties (i.e., risks), the attitudes of the clients toward risk is important. To illustrate with a simple example, a facility which will be sure to cost 2 billion dollars may be preferred to one which has a one-half chance of costing either 2.4 or 1.4 billion, even though the expected cost in the latter case is 1.9 billion. The uncertainty may cause many problems in addition to construction costs per se, such as difficulties in dealing with rate regulation agencies and in financing the project. Value judgments of the client are required to specify their attitude toward risk. Attitudes toward risk are relevant to all concerns, not just economic ones.

Uncertainties in Government Decisions. The actions of the federal and local governments can have a large influence on the relative desirability over time of various sites for a proposed energy facility. For example, a future federal government decision requiring the installation of either pollution or safety equipment on all facilities of a certain type meeting an external criterion (e.g., the air pollution level in the area of a fossil fuel plant, the storm frequency at offshore facilities) could have a tremendous differential impact on the candidate sites being considered now. However, siting decisions must be made now, and uncertainties about future government actions will always be present. Thus, it may be necessary to consider the possibilities of the various government actions in evaluating current siting decisions.

5. Outline of the Decision Analysis Siting Procedure

Decision analysis is a systematic and logical procedure, based on a set of axioms for rationally analyzing complex decision problems. These fundamental axioms are formulated in a slightly different manner in von Neumann and Morgenstern [1947], Savage [1954], and Pratt, Raiffa and Schlaifer [1964]. Decision analysis is developed on the assumption that the attractiveness of alternatives (i.e., sites) to the client should depend on

1. the likelihoods of the possible consequences of each alternative site, and
2. the client's preferences for those possible consequences.

What makes decision analysis unique is the way in which these factors are quantified and incorporated formally into the analysis of a problem. Existing information, collected data, and professional judgments are used to quantify the likelihoods of various consequences. Utility theory is used to quantify preferences.

The decision analysis approach attempts to consider systematically all the available relevant information and to use explicitly the preferences of the clients. This is done by breaking the problem into parts which are easier to analyze than the whole, and then putting the parts back together in a logical fashion. The crucial difference between decision analysis and other approaches that claim to help the decision maker is that decision analysis provides theoretically sound procedures for formalizing and integrating the judgments and preferences of experts and the client to evaluate alternative courses of action in complex decision problems. It is essential to exploit the experience, judgment, and knowledge of both professionals with training relevant to the problem and the individuals responsible for making decisions.

In this section, we summarize the decision analysis methodology for siting elaborated in Keeney [1980]. For the purposes of discussion, it can be broken into five steps:

1. identifying candidate sites,
2. specifying objectives and attributes of the siting study,
3. describing possible site impacts,
4. evaluating site impacts, and
5. analyzing and comparing candidate sites.

The last step involves synthesizing the information obtained in steps 1-4 to evaluate and compare the alternative choices.

Figure 2 schematically illustrates the decision analysis siting process and indicates where the features of siting problems raised in Section 4 are explicitly addressed. Because of this, the quality of the analysis can be significantly increased over that of other approaches which do not address each of these features. This should also help to improve the perception of the analysis.

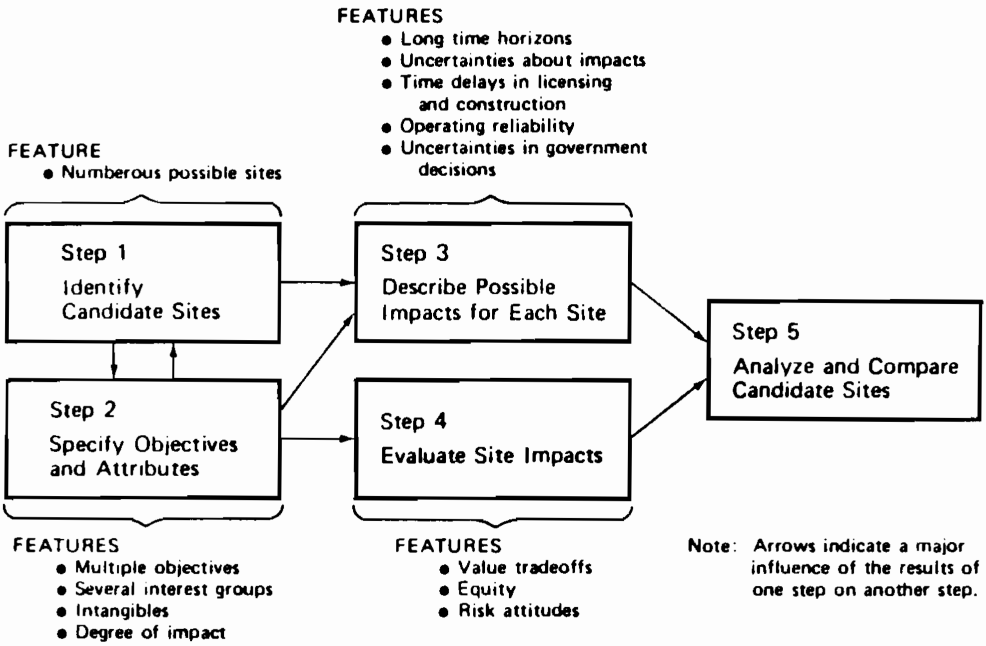


Figure 2. Schematic Representation of the Decision Analysis Siting Procedure

Step 1: Identifying Candidate Sites

Once a decision has been made to build a particular energy facility, the region of interest is usually decided upon. This is an extremely important consideration because it eliminates any site outside the region from being a possible candidate for the facility. Hence, careful appraisal and justification of such a decision are necessary.

Next, a series of screening models is used to eliminate much of the region from further consideration. The purpose is to find a number of candidate areas in which the potential for identifying good candidate sites is deemed high. Some of the screening can be done by legal (e.g., regulatory) requirements, such as the distance from an active earthquake fault. In such a case, the value judgments about acceptability are implied by the law and need not be considered in the siting study. (Of course, such value judgments should always be subject to modification if new data or experience indicates such a change would be appropriate.)

Most of the screening criteria require value judgments to be made by the clients and/or their analysts. For instance, a nuclear power plant requires water for cooling. For one such case, sites more than 10 miles from their source of cooling water were eliminated for economic reasons (see Keeney and Nair [1977]). This condition obviously uses the value judgment that 9.5 miles is acceptable and 10.5 unacceptable. It also implies that distance from the source is an appropriate measure for a screening criterion. Another screening criterion in the same study was that the site be no more than 800 feet above the source of cooling water. Again, this consideration was for economic reasons. In some sense, the value judgment on acceptability of up to 800 feet should be consistent with the 10 miles distance. In fact, a model relating cost to both horizontal and vertical distance from the water source may provide a more useful screening criterion. Decision analysis screening models explicitly include such concepts.

The result of the formal screening is usually a number of relatively homogeneous areas, referred to as candidate areas, in which one suspects the best potential sites in the region of interest are located. Visits are made to each of these areas by members of the siting team, such as biologists, meteorologists, and demographers. Using this information plus other easily available information (e.g., population statistics), the team usually identifies one or more good candidate sites in each candidate area. The process for this may involve the use of screening models, as discussed above, but on a more local level. Alternatively, because of the homogeneity of a candidate area, it may be relatively easy for members of the team to select the best sites within the area directly. For instance, two adjacent sites 2 kilometers apart may be expected, in a specific case, to have the same socioeconomic, environmental, and health and safety impacts, and have the same effects on public attitudes. However, because of the geology of the two sites, it may be clear that one is much better on economic grounds than the other due to construction costs. Such a professional judgment from the siting team would be sufficient to eliminate the inferior site.

A major distinction between decision analysis screening models and other screening models is the degree of attention--both informal and formal--paid to the value structure and the manner in which it is utilized in the model. Not only should this be internally consistent, but it should be consistent with the value structure used in the evaluation of candidate sites once they are chosen. Once the candidate sites are evaluated, the decision analyst should reappraise each of the screening assumptions to minimize the likelihood that excellent sites were eliminated in the screening process.

Step 2: Specifying Objectives and Attributes of the Siting Study

Any siting procedure must specify objectives and attributes (i.e., measures of effectiveness) to measure the degree to which the objectives are achieved by each of the candidate sites. The distinct aspect of the decision analysis approach is the degree of formality with which this specification is conducted.

The starting point for specifying clear objectives is a set of five general concerns. These concerns, which are fundamental to all siting problems, are the following:

the environment,
economics,
socioeconomics,
health and safety, and
public attitudes.

It is not necessary that their domains be mutually exclusive. However, we do want them to be collectively exhaustive so that any possible siting impact of interest is included in at least one of these concerns. The fact that different sites can lead to vastly different implications in terms of these general concerns, motivates us to carefully examine the alternatives. Let us clearly define what we mean to include in each general concern.

Environmental impact refers to the impact on the ecosystem. The elimination or disruption of members of various flora and fauna species are of particular interest. With any electrical generation facility, the construction of the plant and the tranmission line will have environmental effects. Additional impacts of operations occur via air, water, and land pollution and possible radiation. Other energy facilities, such as refineries and pipelines, will also have various environmental effects associated with construction and operation. In all facilities, the disposal of wastes such as spent nuclear material, sludge, liquid wastes, flyash, and by-products also produces environmental effects.

The most important aspect of many siting problems is and should be economics. Basically, the goal is to build and operate the facility at the lowest possible cost, but many factors make this difficult to evaluate.

For instance, there are land acquisition costs, construction costs, operation costs, maintenance costs, and transmission or transportation costs for the product. It is important to note that these costs may include components due to various legal requirements, such as meeting environmental and safety standards, and that these may occur in different time periods over the lifetime of the facility. Furthermore, major uncertainties affect the total costs of almost any major energy facility.

Socioeconomic impact means the impact on individuals living near a proposed facility site, exclusive of health and safety. Socioeconomic impacts are felt in several ways. A major effect arises from benefits due to the taxes which any large energy facility would pay. Many socioeconomic effects occur from the boom-bust cycle associated with the rapid increase and then decrease of people and activity resulting from construction and completion of the facility. This affects the social institutions and economic vitality of the towns near the site. Another socioeconomic effect is the aesthetic impact of the facilities and their operations. This includes the impact of the plant itself, cooling towers, transmission facilities, pollutants, and noise.

The health and safety concerns include mortality, morbidity, and injuries due to normal operations or accidents. With any energy facility, fatalities, sickness or injury may result from construction, acquisition of the fuel, transportation and storage of the fuel and resulting product to, from, and at the facility, pollution or radiation from the facility, and waste disposal. (See, for example, Inhaber [1978, 1979].)

Parenthetically, one may ask why build these energy facilities at all if they are so unsafe as to possibly result in some fatalities. Can we not construct completely safe facilities? The answer is clearly no. It is indeed important to minimize individual risks. However, the issue is: are the risks worth the benefits which are derived from having a facility? It should be evident that no energy facilities are free from potential fatalities and that the absence of facilities would also cause some fatalities because of loss or lack of needed end-use energy.

Many of the impacts on the public are accounted for within the socioeconomic, environmental, economic, and health and safety concerns. However, different sites affect different people (particularly local groups) and these groups may have different attitudes. What is important is the public's perception about the degree to which their attitudes and feelings matter. The manner in which a client uses the viewpoints (and perhaps even participation) of the public in evaluating sites for a particular facility might have major implications for future decisions in the regulatory processes affecting the proposed site. These implications, which could be very important, should be carefully considered in deciding and designing the appropriate public input.

The five general concerns categorize domains of possible end consequences to individuals who will be impacted by the siting of an energy facility. The question one wishes to answer in determining objectives and attributes is, for example, what is the environmental impact of concern in a particular problem and how do we measure it. The process of answering such questions is essentially a creative task. There are, however, several aids which can be employed. Previous siting studies and legal and regulatory guidelines should be of significant help in articulating objectives. To the degree that individuals outside of the siting team participate in the siting process (not the siting study) as intervenors, shareholders, or concerned citizens, they may contribute useful ideas.

From all of this information, an objectives hierarchy should emerge with broad objectives, one pertaining to each general concern, at the top and more detailed objectives further down. The lower-level objectives can be viewed as means to the higher-level ends. Holes in the hierarchy can be identified and filled in by following means-ends relationships.

For each of the lowest-level objectives in the hierarchy, we need to identify an attribute. Sometimes this is easy. For example, an obvious attribute for the objective "minimize construction costs" is millions of dollars. However, it is much harder to determine an attribute for an objective like "minimize visual degradation." This often requires construction of an attribute especially for the problem under consideration. Procedures to do this are discussed in detail in Keeney [1980].

Now we must introduce a little formal notation for future convenience. Let $O_1,\ldots,O_i,\ldots,O_n$ be n lower-level objectives with the associated attributes $X_1,\ldots X_i,\ldots,X_n$. Furthermore, define x_i to be a specific level of X_i, so the possible impact of selecting a particular site can be characterized by the consequence $x = (x_1,x_2,\ldots,x_n)$. An example of an objective O_i is "maximize the economic benefit to the local town," and an associated attribute X_i may be "yearly tax paid to the town." A level x_i could then be 16 million dollars. The desired product of step 2 of the decision analysis siting procedure is the sets of objectives and attributes.

The manner in which the siting problem features indicated in Figure 2 are addressed is as follows: The multiple objective feature is addressed in specifying O_1 to O_n. Some of these objectives can concern the public attitudes so that the several interest group feature is also included here. The intangibles are included by using objectives such as "minimize aesthetic disruption." The degree of impact on this and every other objective is measured by the attribute defined or constructed for the purpose.

Step 3: Describing Possible Site Impacts

It is impossible to describe the impacts of selecting a site for an energy facility in terms of one consequence. The reason is the inherent uncertainties about what the eventual consequence will be. Accordingly, for each site, we want to describe the impacts by listing the various possible consequences and the probability that each might occur. This can be done formally by assessing a probability distribution function $p_j(x)$ for each site S_j. In some cases, the uncertainty about the consequences as measured on some attributes may be relatively small. Then it may be an appropriate simplification to omit the uncertainty on that attribute. Because one can treat $p_j(x)$ in general to include cases with no uncertainty [i.e., where $p_j(x)$ is simply x itself], we will use p_j throughout. The assessment of the magnitude and the probabilities of the possible consequences should be accomplished, when possible, through the development and use of formal models. Such models would define the possible levels of impact in terms of the attributes for each alternative site.

In trying to ascertain what these consequences might be for each of the particular sites, investigations must be conducted within a wide range of disciplines. These disciplines are mainly concerned with the means by which the end consequences eventually occur. Specifically, most siting studies will require information about the meteorology, geology, seismology, hydrology, ecology, and geography of a region. They should also be concerned with the sociology and psychology of the people in that region. In each of these disciplines, there are extensive bodies of literature on techniques for predicting impacts. Because the techniques for predicting impacts for the different disciplines vary widely in analytic formality and scope of predictive capability, knowledgeable professionals in the various disciplines have to be involved in conducting these assessments.

There are several methods for quantifying probabilities in practice (see, for example, Schlaifer [1969] and Spetzler and Stael von Holstein [1975]). One method is to use a standard probability distribution function and assess parameters for that function. For example, the parameters of a normal distribution can be the mean and standard deviation. Another technique, referred to as the fractile method, involves directly assessing points on the cumulative density function. Thus, in assessing $p_j(x_i)$, one is asked for a level x_i' such that the probability is p_j' that the actual level of X_i is less than x_i'. This questioning is repeated for several values of p_j' such as 0.05, 0.25, 0.5, 0.75, and 0.95. By fitting a common probability distribution to the assessed data, one obtains $p_j(x_i)$. A third procedure for direct assessment is appropriate when the possible impact is categorized into a number of distinct (discrete) levels. The expert or client is asked to specify the probability of each. In a short summary, all this sounds rather easy, but it is an involved process with many potential sources for large errors (see Tversky and Kahneman [1974]).

A factor which can greatly increase the complexity of the impact assessments is probabilistic dependencies among the attributes. This means that if two attributes are probabilistically dependent, knowledge about the impact measured on one of them will affect the estimated impact of the other. Clearly, there are such relationships across sites. For illustration, if there are just two objectives, one economic and one environmental, the best site economically is probably not the best environmentally, and vice-versa. If it were, the choice of a site would be simple. Sometimes this may happen, but because one can usually get better environment at a price, the stated relationship of probabilistic dependence holds. Fortunately for siting studies, one is interested in probabilistic dependencies conditioned on a particular site. Since cost overruns at a site have no natural mechanism for influencing the site environmental impact, attributes for these concerns may be conditionally probabilistically independent. However, if there are conditional dependencies, analytical or simulation models which take them into account should be used.

In describing the possible impacts, the time at which the impacts might occur must also be indicated. Thus, the feature of long time horizons is addressed. The other four features--uncertainty, time delays in licensing and construction, operating reliability, and uncertainties in government decisions--are all handled by assessing the probabilities describing the possible effects each of these might have.

Step 4: Evaluating Site Impacts

With the $p_j(x)$ for each candidate site X_j, we have a formal description of the possible impacts. In step 4 we wish to quantify the desirability of each of the possible consequences. Multiattribute utility theory provides the methods and procedures for doing this. A utility function u is assessed which assigns a number u(x) to each possible consequence x. The utility function has two convenient properties:

1. u(x') is greater than u(x")
   if and only if (x') is preferred to (x") and

2. in situations involving uncertainty, the expected value of u is the appropriate index to evaluate alternatives.

These properties follow from assumptions first postulated by von Neumann and Morgenstern [1947].

The preferences of interest in siting are those of the client. They are quantified by asking the client several questions about his or her value judgments. This process of determining the utility can be broken into five steps:

1. introducing the terminology and ideas,
2. determining the general preference structure,
3. assessing the single-attribute utility functions,
4. evaluating the scaling constants, and
5. checking for consistency and reiterating.

For discussion purposes each of these is considered a specific step, though in reality there is considerable interaction among them (see, for example, Keeney [1977]).

The three features of siting problems addressed in this step of a decision analysis are value tradeoffs, equity, and risk attitudes. Each of these require value judgments which are made explicit in assessing u. The decision analysis approach focuses on eliciting and clarifying the necessary information about values and expressing it in a form useful for evaluating the alternatives. The utility function is a value model derived formally from a sound theoretical basis. The assessment procedures systematically include provisions for consistency checks to ensure accuracy. Using the utility function, a sensitivity analysis of the client's value judgments can be conducted.

Step 5. Analyzing and Comparing Candidate Sites

Once the problem is structured, the magnitude and associated likelihood of impacts determined, and the preference structure established, the information must be synthesized in a logical manner to evaluate the candidate sites. The basis for this evaluation is expected utility which, as pointed out earlier, follows from the axioms of decision analysis.

The calculation of expected utility is a mathematical computation involving the probability distribution p_j for each site S_j and the utility function u, all of which are available from the previous two steps. In general, this computation involves the summation (or integration) of the probability of each possible consequence multiplied by the utility of that consequence. This is the formal way of combining the likelihoods of and preferences for consequences. This results in an expected utility $E_j(u)$ for each site S_j which is

$$E_j(u) = \int_x p_j(x)u(x)dx.$$

The higher the E(u) number, the more desirable is the alternative. Thus, the magnitude E(u) can be used to establish a ranking that reflects the decision maker's preference for one set of consequences over other sets. Furthermore, one can transform the E(u) numbers to obtain information about how much one candidate site is preferred to another.

In real-world situations it is extremely important that the client be able to examine the sensitivity of any decision to different views about the uncertainties associated with various levels of impact and to different value structures. With decision analysis, we quantify the impacts (even the subjective concerns), explicitly consider uncertainties, and develop a formal statement of the value structure. Without quantification, it would be difficult to conduct a sensitivity analysis. A useful way of presenting the results of a sensitivity analysis is to identify sets of conditions, in terms of uncertainties and preferences, under which various options would be chosen.

6. Implementation and Political Reality

In some cases, the decision analysis, with extensive sensitivity analyses, may provide enough information and resulting insights that all who have a hand in the site selection process agree that one site is best. Then the client should simply select that site and proceed.

However, in other instances, such an obvious site may not be immediately apparent. A major advantage of the decision analysis model is that it provides the information and methodology to help the client select a site in these situations. Stated simply, the model provides a means for identifying and resolving internal conflicts. Subject to the premise that everyone feels a site should be chosen (i.e., each agrees on the need for such a facility), conflicts about the best site must ultimately rest on either disagreements about some aspect of the analysis or on the interpretation of the analysis. It is much more likely that the conflicts occur about the analysis rather than about its interpretation. In either case, it should be easy to ascertain which is the situation.

If the disagreement is about the analysis itself, it is appropriate to go through the analysis step-by-step to identify the points of conflict. Disagreement about a step is much less serious than disagreement about every aspect of the analysis. In fact, experience has shown (Gardiner and Edwards [1975]) that there is usually much more agreement than disagreement about an analysis, even among adversaries, when the analysis is examined piece by piece. This in itself may provide a sound basis on which to reach overall agreement on a site.

If the disagreement is about interpretation, discussion or perhaps an extension of the analysis is appropriate. The issues of a conflict may be resolved by gathering data not originally available, by conducting additional analysis, and by generating new alternatives, and so on. However, it may be that the conflict has no analytical solution. For instance, two individuals or organizations may maintain, after serious introspection, that different value structures are appropriate for a particular siting problem. In this case, by simply changing the utility function, a siting problem can be analyzed from a variety of viewpoints. These viewpoints can represent any of the multiple clients, regulators, impact groups, and concerned parties if this is desirable. Analyzing a siting problem from different viewpoints provides an important mechanism for the decision analysis to contribute to the political process that is always a part of siting a significant energy facility.

There are two reasons for a sensitivity analysis of viewpoints. First, it provides an evaluation from each different perspective. This may allow us to eliminate certain sites from consideration because nobody particularly likes them. It may even provide enough information to select a best site. The second reason is to identify value conflicts which might exist between clients (or groups) and to indicate actions which may serve to alleviate them. Such actions may involve pollution mitigation measures or quick approval of access to cross federal land.

There is a direct way to do a thorough sensitivity analysis of viewpoints as indicated by the following characterization. Suppose there are three groups with viewpoints expressed by u_1, u_2, and u_3 aggregated into a utility function u where

$$u(x) = \lambda_1 u_1(x) + \lambda_2 u_2(x) + \lambda_3 u_3(x) ,$$

and $\lambda_1 + \lambda_2 + \lambda_3 = 1$ and each λ is positive. We can then use u to evaluate the options. When $\lambda_1 = 1$ and $\lambda_2 = \lambda_3 = 0$, the analysis is completely from the first group's viewpoint. When $\lambda_2 = 1$ and $\lambda_1 = \lambda_3 = 0$, the analysis is from the second group's viewpoint, and so on. By conducting a sensitivity analysis over all possible values of the λ's, we have a rather complete analysis of the implications of the different viewpoints. For some studies, a more involved form of the combined utility function which explicitly considers equity may be appropriate.

The sensitivity analysis may indicate that site A is best using one value structure and site B is best using another. In this case, the analysis may have helped to identify the value conflict, but it clearly cannot alone lead to a resolution. Interpretation of the analysis then includes an understanding of the conflict and its implications. All of this is used to aid the client in reaching a decision.

The possible interpretations of a study vary depending on its purposes. The main caveat to keep in mind in interpretation is that the study examines the siting problem as described by the decision analysis model: This model, as does every model, deviates from the "real world." Thus, the study results must be informally combined with considerations not accounted for in the model to arrive at the implications. Especially when the overall implications differ from model implications, it is important to justify the reasoning.

The written report of the decision analysis of a siting problem provides documentation both for which site is chosen and for why that site is chosen. That is to say, it documents both the decision and the decision making process. Depending on the findings of the study, additional work may be necessary to complement the existing results. In fact, especially for the host of regulatory agencies, it is unlikely that the initial study will be sufficient to answer every question posed. It is therefore important that the model be robust and flexible so that it can quickly and inexpensively provide responses to legitimate "what if" questions which regulators, intervenors, or members of the public may raise. Questions such as "if low-sulfur coal is no longer available, what will be the health consequences of a proposed coal-fired power plant, and would it still be considered best with high-sulfur coal?" "if an oil tanker has a major spill next to the proposed refinery, what will be the environmental consequences?" and "if the values are altered to weight more heavily local community impacts relative to company economics, what happens to the site ranking?" This is a big advantage of decision analysis, since it is usually not possible to obtain insights into such questions with most of the procedures currently in use to select sites for energy facilities. A complete siting study is not only useful for its results, but is also useful as a device or tool to assist in meeting contingencies which will undoubtedly occur along the path to the realization of any major energy facility.

7. Summary

A comment sometimes heard among groups of analysts, regulatory authorities, and managers of energy firms is that what is really needed to help the decision makers is objective, value-free analysis. Simply stated, there is no such thing as an objective or a value-free analysis. Furthermore, anyone who purports to conduct such an analysis is professionally very naive, stretching the truth, or using definitions of objective and value-free which are quite different from those commonly in use. If there ever was an objective, value-free analysis of a siting problem, the analysis and its implications would be of almost no use for helping to make any decision more responsibly. Let me explain.

For a siting problem to exist, the problem had to be identified and this required someone's personal feelings (i.e., judgments). The identification of alternative sites requires experienced judgments in order to focus on reasonably good sites. Specifying objectives (i.e., the noun meaning goals) and attributes entails judgments of perhaps many people, each of whom is naturally biased by his or her own personal and professional experiences. In describing possible site impacts, decisions must be made on how much data of what type to collect, how to use it, and what information to elicit from which experts. None of this can be done, nor should it be done, objectively. It is crucial to obtain, understand, and utilize the professional judgments of various experts.

The ultimate purpose of a siting study is to choose a site for a proposed facility. The analysis is conducted partially to help identify the best (or at least a good) candidate site. The concepts of best and good require value judgments. Some of these involve value tradeoffs between the various objectives, equity considerations, and attitudes toward risk. Other value judgments are clearly necessary in the screening process for alternatives, in selecting objectives and attributes, and in the acceptance of the assumptions on which the analysis is based.

In order to conduct any analysis of a siting problem, the candidate sites must be identified, the objectives and attributes specified, and the possible site impacts described and evaluated. The result is a formal mathematical model of the problem. At this stage, one might refer to the subsequent phase of the analysis as objective and value-free. However, even deciding what sensitivity analyses to conduct and how to interpret the results of the study requires value judgments.

The point is that professional judgments and value judgments are absolutely necessary in essentially every step of an analysis in order to address the concerns and features of a siting problem. Objective, value-free analysis is undesirable because it simply avoids the problem. What is needed is a logical, systematic analysis that makes the necessary professional and value judgments explicit. The resulting analysis should be responsive to the client's needs and justifiable to the public and the regulatory authorities. Decision analysis is uniquely a methodology which provides for such analyses.

All the significant features of siting can be addressed with decision analysis. Some features are easier to include than others. In all cases, the time, cost, and effort necessary to conduct the overall analysis increase with the amount of information required. On the other hand, the insight from a siting study also increases as the time, cost, and effort are increased. Choosing the proper amount of each is an art. However, because the cost and time for a thorough siting study are small compared with those requirements for the entire siting process from conception to existence of a facility, and because many laws (e.g., National Environmental Policy Act in the U.S.) require justifying the siting process in order to obtain the licenses necessary for the facility, it is probably fiscally wise, if not legally necessary, to conduct a thorough analysis.

Experience in using decision analysis indicates that knowledgeable professionals, industry executives, and government officials are willing to address the difficult professional judgments and value questions that are necessary to focus meaningfully on the complex features of siting problems. We believe that the decision analysis approach proposed in this paper will result in improved decision making and smoother regulatory processes for the siting of major energy facilities. Historically, most analyses of siting problems have not provided this. What has been lacking is not information, but a framework to integrate and incorporate it with the values of the decision makers to permit examination of the overall implications of each alternative site.

References

Gardiner, P. and Edwards, W., "Public Values: Multi-attribute Utility Measurement for Social Decision Making," in *Human Judgment and Decision Processes*, Academic Press, New York, 1975.

Inhaber, H., "Risk of Energy Production," AECB-1119/REV-2, Atomic Energy Control Board, Ottawa, Ontario, 1978.

Inhaber, H., "Risk with Energy from Conventional and Nonconventional Sources," *Science* 203:718-723, 1979.

Keeney, R.L., "The Art of Assessing Multiattribute Utility Functions," *Organizational Behavior and Human Performance* 19:267-310, 1977.

Keeney, R.L., *Siting Energy Facilities*, Academic Press, New York, 1980.

Keeney, R.L. and Nair, K., "Selecting Nuclear Power Plant Sites in the Pacific Northwest Using Decision Analysis," in *Conflicting Objectives in Decisions*, D.E. Bell, R.L. Keeney, and H. Raiffa, eds., Wiley-Interscience, Chichester, England, 1977.

Pratt, J.W., Raiffa, H., and Schlaifer, R., "The Foundations of Decision Under Uncertainty: an Elementary Exposition," *The American Statistical Association Journal* 59:353-375, 1964.

Savage, L.J., *The Foundations of Statistics*, Wiley, New York, 1954.

Schlaifer, R.O., *Analysis of Decisions Under Uncertainty*, McGraw-Hill, New York, 1969.

Spetzler, C.S. and Stael von Holstein, C-A.S., "Probability Encoding in Decision Analysis," *Management Science* 22:340-358, 1975.

Tversky, A. and Kahneman, D., "Judgment Under Uncertainty: Heuristics and Biases," *Science* 185:1124-1131, 1974.

von Neumann, J. and Morgenstern, O., *Theory of Games and Economic Behavior*, 2nd ed., Princeton University Press, Princeton, N.J., 1947.

DISCUSSION COMMENTS

SHAREFKIN: I think the hard part in many of these problems has been to figure out what is a sensible procedure for doing the preference elicitation, part of which is finding a procedure and people to really know what their preferences are.

KEENEY: It is often very hard to get the preferences of any of the interested parties expressed in a reasonable way. I think you can get a pretty good representation in many cases. Obviously some people just absolutely will not give their preferences, and would not like to cooperate. These people may be antagonists for a particular case, who feel that the analysis will be used by the people they are against. But suppose you could get a reasonable value structure. The problem you are really addressing is how do you weigh the values of the interested parties, and then put them together.

In a specific context, suppose a particular governmental body has a responsibility for recommending a specific site. In that case if there are three interest groups whose values they would like to account for in their decision, effectively that government body has to implicitly or explicitly weight those three groups. Now as a citizen, I would like to see some of our regulatory bodies do that a little bit more explicitly, because on this I am somewhat of a cynic. I feel many times that the regulatory body considers itself one of those special interest groups and puts about 95% of the weight on themselves and about 5% of the weight on all those other groups out there. And that bothers me. As a citizen I would like them to not be able to put that much weight on themselves.

In addition, I think governmental bodies have a responsibility to promote equity. So, speaking loosely, a site which gave 80% to one group and 20% to another, may not be preferred to one which gave 45% to each. The sum of the former was 20 + 80 = 100; whereas for the latter it was 90. The second was less desirable on the average, but it is distributed much better and may be preferable.

THOMPSON: When taking individual values or preferences into account, one of the troubles is that people do not stay in the same place. Sussex University went to a terrible lot of trouble to find out what students would like, in particular, what kind of buildings they would like. It took several years for the buildings to go up and as the students only stayed there about three years, none of the students whose preferences had been taken into account were there anymore. There were a whole lot of new students who detested the buildings. Furthermore, the same people change their minds, change their preferences, so even if you have not got a fresh load of people there, you often find that their values have changed--in some cases dramatically which we see in the U.S., with the changing attitudes to nuclear power, for instance.

KEENEY: I think you are absolutely right on both of those points. Different people have different preferences so its difficult to find out the preferences of people living in the year 2100 (assuming anyone is going to be living in 2100). However, if there is a decision to be made now which will offset such individuals, the question is: "Do we want to take into account their values?" If the answer is yes, then the issue is what is the best way to do that .

Concerning the issues of peoples preferences changing over time, I think your example indicated that what changed over time was a preference for alternatives. However, of course, the values may or may not have changed. You mentioned that many people have changed their minds about nuclear power. It is possible that the values of these people have not changed, but rather nuclear power is perceived as more risky and costly. Consequently, with the same values, the preferences of the public toward nuclear power relative to coal and other options can reverse. Yet, values certainly can and do change over time.

THOMPSON: The big change in attitudes concerning nuclear power came at the time of the oil crisis when the alternatives were reduced. People began to realize that energy is exhaustible. Yet they turned their backs on the one source of energy that promised almost unlimited supply. There was a dramatic turnaround on the part of many people in Europe and the United States.

OTWAY: I have been following empirical data on the nuclear power issue, and I have not seen any dramatic changes, actually its been monotonic.

BULL: Looking at the framework that you are suggesting, I have come to the conclusion that you are describing a recipe for chaos. The situation you have analyzed in the United States was in some sense unique. For example, the question, 'site or no site' should be left until such time as one has examined one or two sites, including site visits by experts. I have heard no mention of the one word which we frequently use here, the question of "Blighting." As soon as a site becomes a possibility, the minutest question about that site is open to the public, at which point the nature of that site, as a site, changes. One has to ask the question whether it is responsible to put on the table, say, four or five sites, discussion, distress, changes in land values, and so on.

KEENEY: It is possible that my analysis is oriented toward the U.S. This would, of course, be a limitation to what I have advocated. However, I would like to make the point that it is important to decide whether or not you wish to do an analysis. In particular, it is not necessary to make the assumption that there is going to be a site before a comparison of sites is undertaken. Whether or not the best site is good enough, that is, better that the 'no site' option, depends on the qualities of the site.

BULL: As an example for my point, some people were doing an experiment out on the moors, near Buxton, and they were having to wallow around in the mud! They asked me if they could have a firmer base, so I gave the okay for something like one cubic meter of concrete. Since this required an engineer to go to Buxton, the local newspaper reported that "a Shell engineer has visited Buxton to initiate a major development." Of course, what followed was an interview with the mayor, who is reported saying how much "we would welcome the coming of industry, which would help to alleviate the unemployment problem."

RAVETZ: I think you have here an insoluable problem. If you are going to put a big installation on a site, this installation is going to transform it. Your planners either play an open game, which means everything is blighted over all the alternatives, or they play a closed game, which spares people the blight affected environments. But then they are accused of being secretive. I think the problem is inherent in technological development.

DALL: Ralph Keeney said that he thought one could very quickly screen good sites. My experiences show quite the contrary. Quick screening tends to miss things that are not readily apparent. For instance, in California, many of the earthquake faults were overlooked the first time around. There was also no good data in southern California on oceanic conditions (wind and waves). And, most importantly, from the environmental point of view, there was no good data on the local, marine biological conditions. So quick screening tends to mislead people into thinking they have a great site when all they have is a superficially good site.

KEENEY: I agree. What I thought I had said was that one can quickly screen the bad sites--some bad sites. For instance, it is clear that no one wants an LNG terminal within the city of San Francisco.

LATHROP: When you consider David Bull's blighting question, the initial step by the analyst, asking "do we have the project at all?" is, in fact, a step asking "do we take actions that might cause blighting? Do we have enough evidence that we will actually want to site?" We want to have enough evidence that we need a site before we go ahead and start causing blight on the landscape.

BARRELL: This discussion is very interesting and entertaining, but it does not necessarily help us with the real problems. In the UK, we are at a stage where we can, with great difficulty, quantify risk. I am not convinced we are in a position where we can quantify the costs, negative and positive, of averting that risk. For this reason, we should not expect too much from these techniques at this stage. We have, however, gained quite a lot from the discipline of attempting to quantify risk, though many people in the UK, are not convinced that this is an exercise worth carrying out.

We are finding at the Health and Safety Executive that we are getting some hazard analyses supplied to us by UK companies in advance of any legislative requirement. These analyses are revealing a number of gaps in information and gaps in logic, false assumptions, and so on, which I do not think would have shown up had this approach not been adopted. Companies are not happy about doing hazard analyses. They complain bitterly about the costs. And when they undertake these analyses, they are not done well. This is interesting because many of them claim that their existing techniques are entirely sufficient to ensure safe operations. But when it comes to doing a hazard analysis, they often miss out some avenues which could lead to a disastrous event. They make assumptions which, when challenged, are not born out by the base data, and which do not stand up in the dialogue which we have with the company. They learn from these exercises and become more methodical. We learn from them and become more searching and challenging. I think I am personally now convinced that the quantitative approach to risk assessment is beginning to prove worthwhile in some respects. However, I am not yet prepared to agree that it is possible to quantify many of the other things that you talked about.

KEENEY: The advantages of the risk analysis that you mentioned are exactly those that I would hope to achieve. I certainly do not believe that quantification is the answer, but my guideline for whether it is worth trying to explicitly quantify is based on the question "is it part of the problem?" If the answer is "yes," then I would ask "what are the options for dealing with it?" One of the options may be quantifying; another option is thinking about it in your head; while other options may involve some quantitative analysis, but careful appraisal in other ways such as parallel qualitative analyses.

OTWAY: It was not very long ago that many analysts were talking about "objective analyses". People were analyzing risk and saying, "when we present these facts to the public then they will have to change their minds." Then some analysts began to say that analyses are not really objective, but they do help improve our understanding of the problem. But now we begin to hear analysts saying "my analysis can be used to help resolve conflict;" for example, "we can measure the values of different groups and help them to understand each other's positions," that decision analysis can help resolve conflicts. I wonder if analyses are not sometimes dealing with surface issues that are really not about risk and not even about a particular facility. Rather the real conflicts may be due to deeper philosophical issues such as how we want to live our lives in the year 2000—issues that are not really being addressed by the analyses.

KEENEY: There are cases where people do not understand their or other's values. In some of these cases, analysis would improve their understanding and hence, may generate insight about an alternative that had not yet been considered that would improve the welfare for all parties concerned.

MEHTA: I would like to raise two points with Ralph. First, who do you see undertaking this analysis in the first place? Because if you asked the various companies who propose LEG development, they will tell you that they have, in fact, gone through this exercise and they have reached their decisions on the analyses that they have already carried out on site selection. For example, they have screened a number of sites, and have determined which is the best one. In the case of Mossmorran, that was the third site that they came up with in the space of 12 months because the choices that they made before could not be justified. Second, what is the timing of this exercise? In the case of Mossmorran the go ahead was given for its development and yet the question whether or not it is going to be safe is to be determined after it is completed.

KEENEY: The last question is pretty easy for me to answer. Responsibly, siting analysis should be done before the decisions on the site are made, and this is personally where I would really like to see analyses done. Second, I think analyses should be done for any of the parties who have decisions to make in the entire process, including groups that I understand you represent. I have done a couple of analyses where the "answer" was contrary to what the supporters of the analyses had thought, and in both these cases we ended up helping the people see that their initial intuition was really not the best intuition.

CLARENBURG: I want to take up further the point raised by Tony Barrell on where risk analyses can play a useful role. What I would do is take it one step further into the political arena. I am referring to your step 5, which you named "analyses." In the analyses, as you know, you brought together the outcome of risk analyses, economic analyses, values, or equity, and put them in a computer; however, at a purely political level no computer can begin to play a role at all. Take as an example the population of Oxnard. A risk is imposed upon the population, but the people living in a very remote spot have the benefits of guaranteed electricity. How can you make up your equity equation? How can you compare apples and guns in a final analysis, and come up with a computer solution? For political decisions, I cannot use the computer at all because it is really weighing values, benefits, costs, who is suffering, who is gaining. I feel no computer can give this answer, and if it can it is gambling with our democracy.

KEENEY: The computer does not do anything other than very fast arithmetic calculations, and that is all. The point that you raised about equity is very close to the point that Mark Sharefkin raised, and the answer is: "No, this does not guarantee an equitable solution. There may be no equitable site at all." However, as I said earlier, you can have value structures which are trying to promote equity in the sense that they will evaluate sites higher which are more equitable than sites which are less equitable.

SALZ: I would like to ask about the procedure of using multi-objective utility theory. Was this ever used in a real licensing process where regulating agencies, social groups, and applicants have been involved in this?

KEENEY: On procedure, suppose you are a potential user of such an analysis. First, I should indicate to you that it is in your interest to attempt an analysis. A key aspect in doing that is to convince you that I would not misuse your values. It would be inappropriate to assess your values and then just walk away and not give you feedback. I always tell anybody whose values I am assessing that they are welcome to change these. Furthermore, anything I would do with your values or any of their implications they would see before anyone else does, and so you have a veto power over what happens to your values. This does require a little bit of trust on your part, and it is partly up to me to be able to convince you that it is worthy of taking that step.

Now on the value tradeoffs of life, they are tough, but there is not any decision that we are talking about here that does not involve such tradeoffs. There are applications to real cases, but no LNG cases, where the procedures have been used. A local planning department in Alaska used these ideas to evaluate proposed oil storage terminals on Kodiak Island to support off-shore wells. The values used were from the native Indian population, from the local population that moved from the mainland U.S., and from the oil interests. There are no complete siting applications, to my knowledge, explicitly for regulatory agencies. However, there was a risk analysis that I was a part of for the proposed El Paso/Matagorda Bay project, which was an LNG importation and vaporization facility. That was only a risk analysis, not a siting analysis, since a specific site had already been chosen. The risk analysis was part of the safety report that was reviewed by the US Federal Power Commission and was an input to their hearings to decide whether or not to license the project from the safety point of view. For other reasons that facility was abandoned.

SALZ: There is a great difference between risk analysis which presents some of the technical facts and undertaking the decision analysis which comprises all the values which are associated with this decision.

KEENEY: Although I agree with you there certainly is a difference; this does not imply that risk analyses do not have values embedded in them. Every risk analysis has a lot of values implicitly in it. Simply choosing what measures you are going to use implies a set of very strong values.

SINCLAIR: Dick Caputo, at the back, who works on the energy program here. at IIASA, would like to ask some questions

CAPUTO (IIASA observer, USA): Of all the methods to get these things out, probably the multi-attribute utility approach is one of the more powerful. But in trying to understand how to use your theory within a group with a clear set of values, it is possible to do some ordering of important factors and tell that group basically what happens when you accumulate all their prejudices or values or preferences. If they do not like the analyses, they will just ignore what you are doing and go off and do it differently anyway.

KEENEY: There are cases in which I have worked where the values of the decision makers did not give them the site they thought would be best, and they did not then throw the analysis away. In fact, they ended up really trying to learn something from it, and in one case adapted another alternative that they had not at all thought was their best. In the second case, the analysis helped to provide them with information to generate a new alternative which was not initially considered but which was better. Certainly, people sometimes throw all analysis away.

On a related point, I do not view analysis as replacing the political process, which is a crucial part of the problem. If you can get the values from the separate groups, even if you never end up integrating them together, an analysis from these different perspectives may be helpful.

REIJNDERS: I would be convinced that risk analysis was useful if you could come up with some example of study in which there was a convincing argument in favor of an anti-intuitive, non-common sense possibility of solving a problem. Has there ever been such a study?

KEENEY: Good analysis should provide insights so that the level of common sense after the fact is different than before the fact. There are many examples where the *a priori* common sense would not lead one to the alternative which definitely seemed best after the analysis. In one of the cases mentioned above, published in *Operations Research* in January 1979, the first-cut analysis suggested that one site was best for a proposed pumped storage energy facility. When we carefully did the analysis, this site ranked ninth out of ten because of the value that was placed on some environmental degradation that would occur if that site was built as designed. The company, I think, gained a lot of insight from that analysis. It searched for and found a completely new alternative, that utilized many of the desirable features from the previous alternatives and eliminated that significant environmental degradation.

THE SITING PROBLEM OF LIQUEFIED ENERGY GASES:
SOLUTION OR RESOLUTION?

J.R. Ravetz
Leeds University

First may I express my gratitude to my hosts for bringing me here to this brilliantly organised and very important conference.

Ralph Keeney, whose I work I have followed for a number of years, has just presented a persuasive proposal that the kind of siting decision we are discussing here can best be approached by conducting a formal analysis using decision theory. I appreciate the clarity with which this paper reviewed the rational analytic methods of reaching decisions in such ticklish situations which are loaded with pitfalls to mix my metaphors a little. Experts can help in this area and official and public opinion frequently have recourse to them. Clearly we are on the same side of the question and the difference between us is only one of emphasis and nuance. I think that no-one here now, really does believe that there is an expertise of risk-assessment that can produce a fully rigorous, scientific solution to what are in the last resort problems of politics, namely the acceptability of the risks of any particular installation.

We should realize, however, that it is not easy to overcome a tendency to believe that such problems really ought to be soluble by purely scientific means. We have behind us not merely the successes of modern engineering science, but also a tradition of faith in the applicability of mathematics to all problems of the social and human world, which goes back several centuries. This has motivated much of social science, in its effective and also its less effective parts, continuously up to now. I feel that with the maturing of risk analysis, we are facing a new period in this sort of science, one in which very new ideas about what sorts of problems can be solved, and how we should go about solving them, will emerge. I hope that my contribution today will be along those lines, and help this particular conference to generate new ideas about the tasks it faces.

As I see it, what I will try to do is philosophise somewhat on the problem before us; first considering the power and limits of mathematical methods; and going on to reflect, rather more deeply perhaps, on the hazards themselves. I will consider the sorts of problems we encounter when we try to control the hazards; this will then lead me into reflections on what are the soluble problems in this field, and some final comments on what we might do about it. I hope that this will not be too much an extended ramble for your interests this afternoon.

1. Mathematical Models, Statistics, and Inexactness

If I were to indulge in some criticism of Ralph Keeney, and the fascinating paper which he has submitted in advance concerning his methods, it would be on a point of technique of representation. For, looking through it I notice he often uses statistics, or statements of probability, but nowhere does he indicate the confidence-limits of any such quantity. Now certainly, when someone like Ralph Keeney quotes a statistic, we know that he will be using it in a reasonable way. But if someone else is doing this, we have no certainty, in the absence of evidence, that the statistic is being appropriately used.

Now, recently in the United Kingdom, there has been some strong public awareness of the need to cite confidence-limits when producing statistics; even Lord Rothschild, in his diatribe against environmentalists and their ways, where he made his plea for good quantitative proofs of the acceptability of risks, himself admitted that confidence-limits are the essence of the problem. However, I haven't seen much trace of this awareness elsewhere, and so it might be useful if I gave you an example of what I mean. This will be by way of a joke. Suppose someone comes along and says to you, "This coin that I have is a double-headed one. Every time I flip it, it comes out heads." You ask, "How many times have you done it?". And he says, "Once." Your response to that is, "You're crazy." Suppose however he says, "Twice." You then respond, "That's ridiculous." Suppose he says, "I've done it three times." You would still say, "That's silly." So then he comes back to you and says, "Well how many times <u>should</u> I flip the coin and get all heads before you're reasonably confident that it is a double-headed coin?" Now we have a problem. Should it be ten times, or twenty, or a hundred? We realize that the number of tries we require will depend on what is at stake. We will need to decide how much confidence we require in the conclusion, before planning the experiment.

A more dramatic example of confidence-limits involves sampling of materials where an error in the direction of optimism could be costly. Thus, if one is storing artillery fuzes, one would need to be very certain about their stability, in handling and on the shelf. A sampling procedure that was adequate for, say, the detection of rotten apples would be grossly inadequate for unstable fuzes.

My point is, that whenever we receive a statistic, we want to know, before we use it, what are the limits of confidence on that particular number. This depends on the rigor and extent of the test out of which the number appears. In fact, it is more serious than that. Not merely do we want to know this, even for our own purposes; but also we should realize that no statistic is a genuine scientific one, if it has merely been calculated from some existing data, either from a repeated experience or from some observations. Proper statistical method requires that the statistic should come from some particular experience, either experimental or observational, which was designed to test a particular hypothesis chosen in advance, to a particular confidence-limit, also chosen in advance. Without these rigorous controls, then statistical results are what Francis Bacon described as "loose and vague in observation" which are then "deceptive and treacherous in information."

This comment relates to many of the statistics that are produced in connection with the safety of "major hazards" installations. There are quite severe difficulties, since some of the components of the situations are such as to prevent the accumulation of "historic data" of the sort we use in connection with, say, airplanes and automobiles. But when that is the case, we should be made aware of this, so that we know that a figure like "one in a million" might mean, in practice, anything from "one in a thousand" to "one in a billion", to within a ninety-five per cent confidence. You will all remember that after the Three Mile Island accident, Professor Norman Rasmussen said that although he would defend the calculations he had made in his analysis of nuclear reactor safety, he then realized that his confidence-limits were not as broadly stated as would have been appropriate. I think that this problem exists for all these fields, and should never be lost from attention.

Now I want to make it plain that I am not criticising the practice of using mathematical models or statistics. Certainly, in complex decision problems like the ones we face, any formal method which clarifies thought and provides relevant information, is to be welcomed. My only caution is whether this information that comes in is properly qualified to its degree of reliability and accuracy. Certainly, when we are handling these methods we might very well adopt certain rules of thumb which are quite the practice elsewhere in the hazards business. We might have something like a "rule of a factor of ten" so that, for instance, unless two effects differ by at least a factor of ten, they should be considered indistinguishable. Or, alternatively, if a particular effect seems to be near to a danger point, then you take steps to reduce the likelihood of its incidence by either ten or a hundred. The art here is of the handling of inexact quantities, which I believe to be of the highest importance in this work.

I am committed to this very strongly, because it is possible that in some of these problems we find ourselves with methods where the arguments require information with an accuracy for which the precision of underlying data is absolutely insufficient. Such sciences can be called "pseudo-precise." They are in fact a particular sort of pseudo-science, which look like a proper science in some respects, but which are actually incapable of yielding genuine knowledge. The classic example of such a pseudo-science is the old strategy of nuclear deterrence developed in the 1950's around the use of models in the theory of games; Lord Zuckerman exposed this many, many years ago, and I believe that the rationale (though not the practice) eventually became discredited. My point is that it is possible to reason quite eloquently with numbers and higher mathematics and yet still to be talking utter nonsense. How to prevent this, is, I believe, one of the important tasks for scientists and methodologists in the present period.

2. How Disasters Occur

Lest it be thought that I have any particular quarrel with Ralph Keeney, I would now like to turn my critical attention to the organisers of this conference. It seems to me that one aspect of the problem has been very nearly omitted from the voluminous set of guidance notes that we have received. That is, how disasters are actually to be prevented by processes of "regulation." Now, it is possible that they have seen this aspect of the problem as a "given", one that has no influence on the choice of the site or the procedure by which the choice is made. Of course, there is common sense in this, since the accidents cannot occur until after the siting choice has been made, and the construction has been underway. However, it must be said that sometimes the delay is not very great, as we saw in the oil spill at Sullum Voe in the Shetland Islands. Now I believe that this neglect of causation in the control of hazards is an error. I would like to argue strongly that it should be kept in mind for reasons which even affect the politics of choice of sites.

Let's consider now how do accidents or disasters occur. There seem to be two sorts of models that are implied in the different approaches to the problem. The first I might call "stochastic." This is, I believe, pre-supposed in the "fault tree" approach to hazards analysis. We have to deal with certain random events, which each occur at a known frequency. Then we have to consider what happens if several of these events occur at the same time, and produce a concatenation of occurrences, leading to an undesirable outcome. And so if event A and event B are both necessary for a disaster, shall we say, and each occurs at a frequency of one per million years, then we can (roughly) rest secure that the outcome itself will occur only once per trillion years. Thus we can interpret disasters as acts of God, a God (who contrary to Einstein's opinion) throws dice. This approach is implicit, I think, in the study that Ralph Keeney was involved in some years ago for El Paso, which I doubt that he would wish us to take literally in 1980. If I might be permitted to parody the conclusion somewhat, it could run like this: "Now, every time you start a bath, you just get away from that tub and get your tail down to the dockside; you're a million times safer watching those L.E.G. Tankers unload, than you ever are sliding around in your own bathtub."

As an alternative, there is the theory that all disasters are in fact man-made. Some of you may know of the work of Barry Turner in England, who wrote a book with that title; and (perhaps more significant politically) this is the assumption underlying the science called Total Loss Control. The assumption is that if in the first place, an installation under proper scientific control (and we may wonder whether some installations, particularly in the nuclear field are not) then every pathway to disaster is recognised, and is also protected. The protection will be by a combination of physical and administrative or human systems, that both reduce the occurrence of events, and also prevent concatenations. A pathway to a disaster is completed only when there is some sort of "operator error" or "design error" which allows the concatenation to take place. There are always complex causes for such errors, but they always have certain features in common.

As a confirmation of this approach to disasters, we can observe that very nearly every retrospective enquiry into a disaster can discover how it happened. When considering things like Bantry Bay or Flixborough, or Three Mile Island, the Diety is an hypothesis of which the analysts have no need. They always find that the acts, or non-actions, of man quite sufficient to make the randomized acts of God quite irrelevant.

Now I think that this is quite important, because the acceptability of a "major hazard" risk to the people who are going to endure it depends to a great extent on how they feel about their own prospects in the event of an incident, an accident or a disaster. To try to assure them that some purely mathematical science has determined that they are sufficiently safe is, as we know from bitter experience, unlikely to win in all cases. Further, it is unlikely even to be genuinely accurate or fair. What we do know is that a site which is well-run, is safer than one which is not; and one which is properly inspected as well is even safer. And therefore, the quality of the regulation of the hazards will inevitably become an aspect of the acceptability of the risks imposed by any particular site at any particular place.

3. A Pause for Reflection

We must now face up to the possibility that the available knowledge and methods, scientific and practical, might be inadequate for reaching justifiable decisions on these "major hazard" installations. First, the risks of liquefied energy gas installations may be of the "trans-science" sort first defined by Weinberg, where the problem may be stated scientifically but the conclusion lies beyond technical feasibility. Furthermore, our political abilities to regulate the hazards properly, which I recommended as one way forward in our appreciation of this problem, may also be inadequate to the task. Those who have been involved in this sort of work, as I was on the Genetic Manipulation Advisory Group, know just how extremely complicated it is, involving personal psychology, political attitudes, administrative traditions, and even some highly reflexive aspects of ritualised behaviour.

In the light of this and other experience, we now know that there is no easy way to the totally effective regulation of hazards. Because of this, we may find ourselves lacking genuinely "demonstrative" arguments on even the technical aspects of a siting problem. Under those circumstances, obtaining a real consensus, by the use of reason and genuine persuasion, becomes doubtful. I believe that this is a serious problem of politics in our high-technology civilization. For if we are unable to obtain consensus on these siting problems, then these installations, which are peculiarly vulnerable to local protest, either during the planning or construction, or even during operation, will be at risk; if not from a physical disaster, then from a stoppage by administrative or human causes.

Faced with this situation, the scientists among us might do well to recognize the emergence of a new sort of intellectual exercise, or problem. I would not want to reduce it merely to "trans-science", for it has more dimensions than the merely cognitive. We might call these problems "policy-science"; and in them the task is not so much a puzzle (in Kuhn's sense) to be solved, as a dilemma to be resolved.

Scientists who are embarking on such problems should realize a very deep difference between them and those of traditional research. This can be quite disorienting; I shall describe it as an absence of "facts." That is, scientists cannot hope to base their conclusions on assertions about the world that are reliable under repeated testing, and also stable under extended use. This is clearly the case in the analysis of the risks of "major hazard" installations. The data-base is too small, and the confidence-limits of any scientifically-derived probabilities are too wide, for conclusions of a traditional strength and solidity ever to be derived.

My personal experience of the regulation of Recombinant DNA research has convinced me that most scientists find themselves in very unfamiliar territory when coping with such problems. Even though the results of research in an active field are often contested and perhaps speculative, scientists have the security of knowing that some of them at least will become "facts", and these can serve as a foundation for other work.

If the desired outcome of the work were the accumulation of positive knowledge, then this might be a desperate situation indeed. But in the "policy science" area, the end is not new knowledge but a decision. And that decision, as we all know, is multi-factorial, with the science only one aspect among several. Therefore, the science that we do in this context, however much it must be disciplined in its own right (and I reminded us of this in connection with Statistics) could well be oriented around a new sort of task. This would be instead of the old "solving problems" it would be "resolving dilemmas."

Proceeding, perhaps too rapidly, along my speculation, I can see a new conception of the scientist's role emerging, along with an appropriate etiquette and ethic. The scientist's work results not so much in demonstrated conclusions as in conjectures, made under conditions of variable but always considerable uncertainty; and where the problem as conceived, and the values put upon its solution, strongly condition the experimental research which underlies any assertion. We may then see that in such cases a prior policy commitment is both inevitable and indeed honourable. In other words, we would then begin to model the debate on a forensic situation, and to treat our scientists as committed "expert witnesses" rather than as judicious advisors who are supposed to be disinterested in the outcome of the case.

Now, those who are familiar with the frontline of research in any experimental field knows that scientists are fully committed to their own work and may argue quite passionately for one conclusion over another. However, there are some systematic differences between the roles that are involved; I think that we might say that in "pure research", a scientist really should drop a particular opinion when the weight of evidence has gone very strongly against it, regardless of his more far-ranging interests in one line of solution to the problem. Whereas in this policy-science, where vast resources may be at stake, it is entirely appropriate and honourable for an expert to resort to one line of argument after another (all of them apparently quite impeccably technical), in the interests of the longer-range commitments which he upholds on behalf of his organisation.

I believe that with a recognition of this aspect of policy-science, there might be a much clearer understanding of what scientists are actually doing when they debate in these cases, and a more properly structured debate might then take place. This has some similarities to the "science court" idea; except that that particular scheme pre-supposed that there were "objective facts" to be discovered which would serve as the nucleus and determinant of an ultimate solution. I do not think that such an assumption should be invoked, since it would be difficult indeed to substantiate.

Furthermore, when we have seen how the supposed hard core of scientific and technical content is in fact so infiltrated by uncertainty, we then should have another look at the policy problem itself; because now we might see that it is not at all easy to imagine the politics and administration being neatly wrapped around the outside of the technical problem; they are all mixed in together. We might then ask what sort of criteria could we have for optimising solutions to a siting problem; or even ask the deeper question whether there is any certainty that such an optimum could even exist.

4. What Could be a Soluble Problem?

We all know the deep, practical difficulty that has brought this study into being. Every "major hazards" installation must be somewhere, on some site which presents not only physical hazards to its environment, but also possible political obstacles to the programme of its construction and operation. Also, as I have indicated, our scientific and practical knowledge might be inadequate to the tasks of producing a siting decision which is "acceptable" both in practice and principle. This may indeed be a basic contradiction of our present high-energy material culture. We now find that there are some costs of this technology which cannot be exported to the powerless, either our local poor, or the colonies, or the biosphere. These "major hazards" become salient locally and cannot be shoved aside; we have seen this phenomenon already with airports and some highways. The question can no longer be ignored: who will pay the costs for these installations, in the acceptance of their hazards; and furthermore, why should it be they?

I would like to suggest in considering that sort of problem that we adopt a method first proposed by the former Vice-Chairman, and also founder, of the Council for Science and Society in London, my former boss Paul Sieghart. As he has said, when we look at a proposal for solving such a science-and-society problem by combined physical and administrative means, we should consider three things. These are: the criteria by which the problem is defined and deemed solved; the procedures whereby actions are taken and monitored; and finally the agencies (people in particular corporate roles) which are responsible for choosing criteria, for taking action and for monitoring. If you unpack that set of recommendations you find a very complex set of things to be looked at. However, I think that with that sort of structure in mind, it can be possible to make more progress on the problem.

Given that method, we can consider the different sorts of problems which offer a hope of being soluble. I fear that the general siting problem is not one to which we can give a uniform, overall solution. There are so many particular and local circumstances involved in this, that it is difficult to thread one's way through, to obtain criteria for an optimum, except perhaps those which apply to the decent and competent operation of technology policy anywhere. Of course, in some cases, it might be highly relevant, perhaps even subversive, to introduce such criteria. So perhaps I should say for the record, that there must be an element of scientific competence, including the judicious use of quantitative methods, in assessing the risk; and there should also be proper administrative procedure, within the traditions of each nation, in the making of the choice. However, going beyond that into more detailed recommendations, I do find myself embarrassed.

We also have here an important aspect of the theory of politics, which is only now becoming developed, perhaps more in America than elsewhere. This deals with the problems arising where the traditional theory of a division of labour among the different arms of government becomes almost irrelevant. The role of the Legislature in such situations is minimal, and that of the Judiciary is marginal at best. .So then we have the Executive operating nearly alone, perhaps with some quasi-State agencies, balanced only by extra-constitutional forces, be they of pressure groups or other corporations. This seems to me to be an important aspect of politics in the present period; those who are studying the British Parliament in this technological age are keenly aware of it. However, we have not made much progress in producing effective solutions to this problem, and certainly none which I could offer for detailed guidance on the siting problem in general. I regret very much that I cannot say more in a positive way; the list of problems and criteria that are offered are in your outline, is very important indeed; but I confess that at the moment of preparing this lecture I am somewhat overwhelmed by their comprehensiveness and variety.

I therefore fall back, perhaps rather timidly, to the aspect of safety. For I do believe that in spite of the many difficulties I have discussed already, there is at least the possibility of argument about the hazards of an installation; and of at least the possiblity of comparing a more or less hazardous approach to construction and operation. Here Paul Sieghart's principle of analysis could be applied quite directly; and also the imposition of a special burden of local risks should also be recognised. That is a general principle; for my sequel I would offer a maxim of practice. This is, that without the continuous monitoring of a hazardous installation, with attention to whole chains of responsibility and command, and also check-ups and emergency drills, we can be fairly sure that a site is unnecessary hazardous, and therefore an unfair risk to be imposed on a local population. This, of course, fits in with the approach of Total Loss Control; since it reminds us that disasters are created more by the omissions of man than by Acts of God.

5. Concluding Remarks

I hope you will forgive me if I indulge myself in the temptation to go rather philosophical at this point. I think I am indicating that the old antithesis between science, which is the "art of the soluble" and politics, which is the "art of the resolvable," is too sharply drawn. In fact, in these most important problems, there is both science and politics involved in each and every particular problem. All these problems are of the sort that E.E. Schumacher described as "divergent problems", where values are inextricably involved, and attempts to push the solution to one direction or the other can lead only to incompetence on the one hand, perhaps, or to tyranny on the other.

Now, faced with problems of that sort, without the hope of a totally impersonal "objective" solution, scientists and philosophers of a traditional cast would say that we are in the realm of the "subjective" or perhaps even the "irrational." If so, this would be most unfortunate, for to me these are the key problems of the future; at least they are the problems of any science where human interests are affected in any direct way.

Fortunately, I believe that my example of statistics shows that the situation is not at all a new one, and that indeed it is possible to develop some techniques for handling it. Indeed, when we look at any quantitative statement, in any field, and realize that in order to be meaningful it must be qualified by some degree of inexactness (which itself has inexact limits), we see that the interpenetration of the "objective" and "subjective" is complete in any discipline whatever. Does this mean that we lost objective knowledge? Of course not; it simply means that our idea of having scientific knowledge standing totally free of humanity, available to be wheeled into place like a machine, has been over-simple and misleading.

I believe, therefore, that the practical difficulties of coping with the hazards of our high-energy installations, be they nuclear or "conventional", are bringing us, not only to new tasks of society, but to a new philosophical conception of what scientific knowledge, and scientific practice are about. If we ignore this aspect, and pretend that somewhere, somehow, there is or should be a totally impersonal expertise out of which we can churn answers to basically human problems, we are at risk of incompetence and failure. But with an honest understanding of this new situation for human knowledge, I believe that we have some chance of coping successfully with the difficulties that our marvellous new technology has created. And this conference, where the problem has been displayed so extensively and deeply is, I do believe, an important step forward. Thank you very much.

PRESENTATION BY J.R. RAVETZ

SINCLAIR: Jerry Ravetz will present his views on the subject of analysis, and attempt not to overlap those points presented by Ralph Keeney.

RAVETZ: I have just had to solve a difficult statistical problem, namely how much of my prepared text should I read. You all know these difficulties with a prepared text, you assume people have read them and the text turns out when you read it to be a little bit unfamiliar and most of it a bit stale. So then as the discussion proceeded today, I could see that really in the context of this group now, I was not as provocative as I had hoped I would be. Therefore, I began to modify my content a little bit more And I then thought that I might as well add some quite provocative comments at the end for interest. Then Harry Otway told me that for personal reasons he has to leave early, so I thought I would put my provocative comments at the beginning. So I will merely start with provocations and if I get back to the text, then that will be useful. Before I start the provocations, I will take some time to say something in support of Ralph Keeney's approach. Simply this: "Yes."

I teach the history of science and I have a number of little set pieces in history, particularly that mathematical methods do not come to full maturity and effectiveness over night. One of my favorite examples is the pendulum which was discovered more or less experimentally by Galileo as something that goes back and forth, where you actually have a regular, periodic phenomenon you can tell time with. Galileo got very excited about the pendulum, built much of his mechanics around the phenomena of the pendulum and derived some extremely interesting theorems which were wrong. The pendulum was then used as the basis for timekeeping. Some brilliant work was done by Huygens, the Dutch natural philosopher, around it, in the hopes of solving the problem of longitude; and in that he failed. And finally the pendulum, as the foundation of a truly effective timepiece, was given full technological achievement some 150 years after Galileo discovered it. So the moral is: "Even though your mathematical techniques are a little bit immature, this does not mean that they are useless or stillborn or more harm than good." I think the history of the development of particular mathematical techniques in the social sciences and also in the natural sciences is one of "over-enthusiasm" down through the centuries, and if, in the course of only a few years, we have come to have more sober and realistic appreciation of the power and limits of these methods, then I think that shows we are doing very well. So much then for the nice words.

What I am going to say does not contradict anything that has gone before, but I think it will enlarge the debate somewhat. I want to talk about "incompetence" and "tyranny" as components of large scale technological decisions. Now perhaps the best example, the one that alerted me to this, was an early case of a siting decision in, as you may expect, the earliest civil nuclear reactor in the State of California, involving, of course, poor old Pacific Gas and Electric. This was at a place called Bodega Head, and the site was chosen after a survey. Environmentally it was extremely good; it was on the coast north of the populated regions and yet not too far north for convenience. Hardly any population was present, and the site is cooled by the waters of the Humboldt current coming down. Also, there is a little peninsula made of rock where you could put the reactor itself; thus it was absolutely perfect; for the engineer, a dream. Now from the point of view of getting the land it was not too bad, because some of the land was controlled by the University of California whose Chancellor then was Glenn Seaborg who was in the nuclear fraternity. And, in fact, the whole plan to build a reactor there got far ahead before anyone noticed. I think they were held up first by an old lady who simply did not want people driving a road through her private forest with all those nasty trucks coming through. She refused to sell, which meant that the operation had to go public in order to take the land from her. Then when it was a little bit public some people at the University on the Berkeley campus realized that some plans for developing a nature reserve at Bodega Head had gone peculiarly quiet. They made inquiries and discovered the reason was that the site was to be used otherwise. So that made them cross and the naturalists joined in with the old lady. Then a geologist employed by this university (recall that this is a free country), thought: "where does the San Andreas fault run at the latitude of Bodega Head." And so he got into his car and drove up, and walked back and forth in the woods and every time he found evidence of the fault it got closer and closer to Bodega Head. So then there began, perhaps the very first, of these environmentalist campaigns agains a major installation. Immediately Pacific Gas and Electric said "You are crazy, you are irresponsible, our engineers have assured us that this is the one and only, the unique and perfect site." And they fought very bitterly using all the tricks at their disposal, and so finally the Atomic Energy Commission had to say some five years later, "We do not care if you have done a lot of site work, we do not care if you have already dug a big hole in the rock. Unfortunately, until we are satisfied on the safety aspects, given the geological problems, we will not supply you with nuclear fuel." And of course, that then killed the project. And it eventually emerged that the site was very badly faulted indeed.

I then began to say "How could this happen, especially in the State of California, which is a very highly developed and civilized place?" I then reflected on "incompetence" and "tyranny." I use these terms not as attacking anyone personally, for I think there are tendencies both to incompetence and to tyranny in these large-scale operations. Such tendencies are to be found anywhere, but they are particularly strong in these cases. And as we see from these major hazards installations, they are particularly dangerous. But let me say I am trying to show these tendencies are natural, and that honorable men and even honorable ladies can be caught in the patterns of behavior of which I will be describing.

Why should there be incompetence? I think this may be in part a time-lag problem, because these environmental problems, as pollution and "major hazards," are new to engineering practice. You might say that earthquake problems would be fairly familiar in California, but then the sensitivity of a nuclear reactor to earthquakes is far greater than that of a conventional boiler, and so an awareness of faulting is more relevant to the engineering of a nuclear reactor. If you look at the pollution problem, we all know that the concern with pollution has come late in our history of industrialization. So most established engineers never encountered these things in their professional formation. The problems of hazards are particularly difficult. The task of guarding against hazards is really a weird thing because you succeed when nothing has happened. That conception of success--ensuring that nothing happens--is very alien to the way we organize our activities, the way we value ourselves. I think this deep psychological difficulty immediately makes it very hard for a conventional engineer or scientist to cope imaginatively with hazards. Moreover, in hazards we are involved with a set of problems that are traditionally on the fringe of engineering practice. These have suddenly become central to the design problem; and it requires unusual imagination in individuals and in organizations to cope with them without a time-lag of at least five or ten years.

This is why there is a tendency, which is not by any means universal or uniform but is real, that whenever there is a conflict between a local or special-interest group opposing a major development, and a corporation that is proposing it, the tendency has been for the opposition to have greater technical competence on the environmental problems than the proposer. And this is only reasonable. It is absolutely central to the opponents; they do not care how economical or cost-effective a plant is, they only care about the environmental aspects. They train themselves up, they hire expertise, they work on it night and day, while for the corporation this problem is just a nuisance. These engineers and experts are not irresponsible, but their job is to get the plant built and onstream. Its almost analogous to the phenomenon where the prisoner is always outwitting the jailer, because he has time to sit there and think. So, therefore, I would argue that incompetence of this nonculpable natural sort, is something to be reckoned with whenever there is a new project which throws up new problems of this sort. There is a time lag effect, there is a learning course which goes on, which modifies that corporate incompetence and this is why I speak this way without being harsh and judgmental.

I think the learning has now been going on quite rapidly. An example came to me when I was talking to Ned Franklin who until recently had been the big man in British Nuclear Fuels Limited, which runs the famous Windscale reprocessing plant. At an informal conference he was reflecting on this intriguing problem of risk assessment, in terms of "quality assurance" at components. If a particular thing is to have a failure rate of less than 1 in a million, "then," he asked, "how are you going to do this, unless you have something like a million copies or a million events for your data base?" Thus, he had come to see one of the very, very deep and perhaps insoluable problems of a quantum-leap innovation in a major hazard high technology. If you do not have a lot of historical data you cannot really give a quality assurance. Now if I think I or anyone else had said that to Ned Franklin at a public debate a few years ago he would have been very impatient and replied "You do not understand the problem." But I think we have all matured, and I think just as the old and new examples of California show, the oppositions' points of view have been learned. Thus, given a planned installation, it is not good enough to bounce the thing up and down the coast indefinitely. It has to come to rest sometime, somewhere. I think the engineers for whom the environmental problems were marginal and on which they were at first incompetent, are now learning very quickly. But on the other hand, I think we must still cope with the possibility of institutional incompetence and not be shocked or scandalized by it. It is a natural feature of a rapidly developing technology.

Now to "tyranny". That is a terrible thing to say, and I am not sure tyranny is the right word. I am thinking here of the use of power without effective restraints or responsibility. Let us say unrestrained power, as I think "tyranny" means something slightly different. Speaking very broadly, we can say that people used to believe that largely unrestrained power could be wielded, with some legitimacy, and therefore, effectively and permanently, but only by people with a noble title. If you were the Duke, and you owned the whole dukedom you could push people around, kick them out, string them up, break the daughters on their marriage night, and you were okay. And then a couple of centuries ago people believed that if we got rid of aristocrats and we had a democracy and capitalism then we would have freedom for all. These then developed, but there was still the power of sheer wealth. So that even under a normally free and democratic society those who had great wealth again were able to exercise tyranny, if not over all of the whole lives of the subjects, then maybe just over their working lives. Even to this day if you go inside a factory, especially one that does not have trade union organization, there you may see a fair measure of tyranny going on all the time, usually in petty things, but very real nonetheless. People are always free to leave and walk out on the street and starve, or go on the dole. But otherwise you have harsh arbitrary unconstrained power, of course more in poor countries than in rich ones. So the point then is, that wealth brings power which is also tyrannical in its sphere of operations. The movement for socialism was partly a reaction to this type of power. But recently, I think, in many of the advanced countries (even in democracies) we discovered that tyrannical power need not have either blood nor wealth for its basis; it just needs bureaucracy, state or private, but usually mixed. The power is not absolute, as was seen in the case of Bodega Head and Pacific Gas and Electric, but it is real.

In studying this power, it might be misleading to concentrate on these big cases. One of the lessons of environmental struggles of the recent period in Britain is that such arbitrary power does not even need big bureaucratic decisions for its exercise. One of my own great political lessons was when there was a move by the city of Leeds to bring "urban renewal" to a neighborhood which was right next to our own. The technique was to say that all the houses there were "unfit." And as such they had a "life" of less than fifteen years, therefore they could not get renewal grants, and therefore they were going to fall down, and therefore they must be pulled down soon. Now the people who decided this and decided which houses were doomed, were not even big people. I confess the fierceness of my reaction to that case was partly because here was some 25 year old kid with some mediocre degree in planning, who was saying all these things, and was going to destroy hundreds of thousands of pounds worth of sound property, blight dozens and dozens of lives, simply because he had drawn some curves on a map in accordance with certain fashions of the time. So we went for him. It was a political education. He learned too, and now lives in the "conservation area" which we saved from him. The story has a happy ending only because there was enough middle-class expertise and connections to defeat that particular plan; elsewhere, where it is only workers' homes being improved, arbitrary planners' power rules.

Those who have discussed political theory of modern societies have identified a type of bureaucratic tyranny which has a characteristic property that you cannot even find the guilty person. And this is partly because the great principle of bureaucratic inertia that any existing policy, however bad, is to be maintained and defended at all costs. When in a large democracy, however enlightened and benign, a policy has crystallized, regardless of whether anyone actually decided it, there are bureaucratic, personal, and career investments in that policy. Regardless of the difficulties that arise, it is a natural thing for the whole bureaucracy to go ahead and fight for that policy until it is forced by external coercion to change its mind.

In this case you can have a sort of tyranny coming from people who are like you and myself, not because we are nasty, but simply because it is an inherent tendency in the way in which our technology operates, given our political and social history and also a convenient style of operation. Now let me make it quite plain, that those who act irresponsibly are not necessarily big bad men in Pacific Gas and Electric or even little men in housing offices. They can also be people who do not wish their lives disrupted by a particular installation; and if they have the resources or education and political connections and organizational skills, then they too can operate a machinery of "due process" in such a way that they can hold up or destroy a development which everybody else agrees is necessary to be put somewhere.

So I am not saying that only bureaucratic people can act irresponsibly; obviously anyone can act irresponsibly. I am saying, however, that in these actions, even when one is using the due process machinery, it is easier to be irresponsible and tyrannical if you are already locked into the bureaucratic system. You simply have more leverage, that is the way politics works in our sort of society. Perhaps one of the few cases where a major bureaucratic decision was overturned in a straight political way was in connection with the Third London Airport. The siting problem was already a mess, and as it happened there was a rather upper-class action-group fighting on a very emotional basis advancing slogans against putting an airport in their beautiful rural valley. Because the proponents were already weakened for various reasons, the defenders were able to win their struggle. But normally, as we know, bureaucratic power, financial resources, and personal connections weigh heavily.

Now you may say, what is new in all this? We have had incompetence of all sorts all through history; in fact, our societies are at this stage far less incompetent than ever before. And certainly we have had tyranny for a long time usually far more than now. I think what is new is that this incompetence and tyranny, or better, the tendencies to incompetence or tyranny are practiced in the name of Science, and this is what we find so difficult to comprehend. Our idea of Science, derived from the history of science, is something which simply does not fit in the same book with either incompetence or tyranny.

I believe that this is possible, partly because the "science" that is used or deployed in these policy debates has certain deep differences from the "science" created in research labs, which has long been the object of history, philosophy, and myth. As a technical innovation it may be interchangeable in some respects with the products of traditional academic or pure research, but as a social possession it is quite different. So it is possible then, given the communities and organizations that are involved, given the functions to which this material is put, to operate very successfully while still committing a number of abuses of the public or ostensible conventions of objectivity of information, publicity of materials, openness of debate, and all that sort of thing. I think it can be argued, and argued well, that if you are abusing the procedures of science, in this case, you are likely to impair the quality of this science that is done. You then make more room for the reopening of debates on competence. But I think it is necessary to understand that there is not a total logical impossibility of this type of political manipulation of results produced in labs which are outwardly "scientific". It may well be corrupt, but it is quite feasible.

When we are dealing with this sort of science, the political game then involves something which can be called "regulating the regulators". I first saw this discussed seriously in a very deep book on society and its imperfections by the American "muckraking" journalist Lincoln Steffens. In discussing corruption he talked to the President of the Sante Fe Railway and asked him "Why do you do these corrupt things? Why do you always bribe legislators?" Steffens was a very good journalist, who did not condemn such people. He was level with these people, he knew that they were doing business; and they were quite interested in explaining themselves. This man said, "Look, my duty is to the shareholders of the Sante Fe Railway. If the state of California proposes to regulate the railroad, my job is to regulate the State of California." And Steffen's Law then is that those who are regulated must in turn try to regulate the regulators. Now this is done in ways which depend deeply on national cultures. I know the way its done in the states: The regulatory process tends to be ostensibly very "adversarial," but is then mixed in a very incoherent way with straight corruption. In Britain it is much more gentlemanly and really much less crudely corrupt, and much more consensual, cozy and complacent. I will leave it at that. You get totally different styles of "regulatory interactions," they are totally incomparable in their effects, you cannot translate one to the other, and they depend totally on the national culture. I should like someday to be on the continent to see how the game is played here. I find it impossible to believe that there is a game not being played—"regulating the regulators." Now when I say "regulating the regulators" my point is *not* that the industries manage the regulators like puppets, anymore than the regulators manage the industries like puppets. There is a power struggle all the time, but let us say the process of regulation is one which is reactive or reflexive.

Some people might say that this is being cynical. But like Harry Otway I would say, "No, I am not cynical, I am a realistic." This is an old game, which I think is quite familiar and is quite polite to discuss in American "Political Science" literature about government. But I do not think its polite to discuss anywhere else. And this again is another example of national styles. What makes it serious, the old game of power, incompetence, of manipulation of regulatory process, what makes it more urgent now is that these industrial processes, unless they are controlled, might blow up in some small or larger part of the human race. If we fail to have effective regulations of liquid energy gases installations, we could find ourselves with what has been called a civil holocaust. There is a risk, small but finite, of something going very wrong. Now this is why perhaps the old established folkways, whereby power is negotiated within society, are not quite good enough anymore, because our technological machine requires a higher standard of competence and of integrity for its safe operations than previously. We cannot afford anymore to learn from our mistakes in technological innovation. This was the slogan from the beginning in the nuclear power business, and I think they have certainly tried even with all the recent unfortunate occurrences. Still less can one afford to learn from mistakes in this liquefied energy gas, and perhaps other technologies to come.

Since the problem of the imperfections of regulation, and the causes of it, as I said, are deep in our culture, I think we can also see that the solution does not involve us in making arbitrary or artificial choices. For instance, I was pleased to see Ralph Keeney saying, fully agreeing, I suppose with everyone; "We cannot demand that a risk analysis have the sort of scientific objectivity as if it were a theorem in pure mathematics." We know that someone engaged in this work is involved in a political and a power struggle. Even if he comes in as a purely independent observer, the information which he has, is loaded with power. It will generally favor one side or the other; if he releases it to the media, it will be used; if he holds it secret, that is also an act. So, therefore, what you find is that once involved in these things, one is involved in rather traditional sorts of *political* activities with new slogans, with new styles and new issues. And I think, therefore, that to try to hope that pure reason will settle it, is utopian.

On the other hand, it is not a question of the simple abandonment of objectivity and integrity, as if every technical expert could say, "Oh I am just a hired hack for one side or the other." I think there has been a tendency, because of the inherited ideology of science, to imagine that unless a scientist is totally objective, totally alienated from human life, he is then a prostitute. I recall studies in the sociology of science which reported (and reflected) the prejudice of leading American scientists who viewed their students who went after industrial work as having foresaken the temple of science and prostituted themselves. If you have that type of naive dichotomy, they you are simply not at all equipped to cope with these new problems. When one looks at other fields where people have used knowledge in situations involving power, there are a whole set of roles which unfortunately I have not properly sorted, but I will indicate just to show you that there are totally honorable and ethical ways of being involved in more ways than one, in the use of knowledge in the struggles concerning power. Let us say that at one extreme you have your scientist who makes a discovery and then must decide whether or not to release it publicly. You can have someone who is a consultant, who after all comes into the case only when somebody pays him to do so, and then has the problem that Ralph mentioned: "What do you do if your client does not like your results and advice?" Well, that is a problem. You may then have an expert who has technical competence, but is employed by one side, he will handle these complicated issues in a different way. You may have an advocate, appearing in a formalized proceedings, whose job it is to argue for his client, not to judge his client. Like the lawyer, he will handle his material and the problems in this material in yet a different way. Finally, you may come to someone who is straight adversary, who is out there demonstrating and to him it does not matter ethically if he stretches the facts, because he is struggling against big corporate power. Maybe at the far end you have someone who goes over the fence, sits down or smashes the machinery, and so forth.

Now I would argue that in this whole spectrum of positions, consultant, expert, advocate, adversary—it is possible for a person to argue or to behave in a consistent and honorable way. But the roles are different. I would fear confusion and corruption, when people are not aware of their role and will tell other people, or worse yet tell themselves, that they are in one role while behaving in another. Then you can have real, real troubles. I find these problems quite fascinating because they are forcing us to reappraise our ideas of what is science and what are scientists. I am always interested to see new features of the problem because I think these are urgent, and also to be reassured when I see that there are thoroughly traditional features, because it shows that we do not have to throw away everything that we ever learned about the practices and the ideals of science. So if I can find continuities, if I can find that in many ways we have been doing it already, then I am cheered up.

Now there is one small point I mentioned in my paper, I think near the end which may be useful. It is pretty clear that the handling of quantities particularly stated probabilities in these debates is very unsatisfactory. One of the Californian papers has made this point, that however you state a confidence-limit, how ever you state the qualifier on a particular probability, that itself is a political act. If you can say, "its one in a million to within a thousandfold at 95% confidence," people can say "I do not want 95%, I want 99%;" that game can be played. Or if someone gets his mean probability and then is conservative and quotes the "pessimistic" end of the range immediately people say "Oh, you say its 1 in a thousand," when you really meant 1 in a million. Because if you say 1 in a million to within 10^3 at a 99% confidence-limit people calculate 1 in a thousand and pick up on this as the significant number for policy purposes. So the point is, handling these estimates becomes a fiendishly intricate thing, laden with misunderstanding and political implications.

I do not know an easy way through it, and in fact this thing used to scare me. However, all I can say is, the problem, although far more acute and politically laden now, has been with us in the practice of competent handling of numbers, way way from the beginning. In any experimental science, or any numerical quantitative science, people have always made qualitative judgment about their quantitative statements. If you go into a physics lab and you say the value here is 6.23 then they will want to know to within what, 1%, 5%, or what have you. I remember this vividly because whenever I did an experiment in college physics I always had an "error" that was more than that allowed, maybe twice as much, and certainly never quite good enough. In fact, you find that when people handle quantities they have implicit conventions to convey the qualitative judgments of inexactness; and without such a judgment the statement is meaningless. So we have the "significant digit" conventions and we have all sorts of more sophisticated conventions in special areas. In fact whenever we have dealt with quantities we have always presupposed qualitative attributes of them, we have hardly ever needed to think about them, and for that reason some really amazing nonsense has come out of various sciences, largely social sciences, simply because people were ignorant of the craft of handling quantities. But if we look back on our own successful practice we see there is a craft there, that every quantitative statement involves policy decisions. Someone, I think Ralph, even mentioned what do you do in your handling of aberrant data, even in a physics lab, reflects your belief about the cosmos. Its as simple as that. If you throw them away its because you believe the world is regular. If you hold on to them its because you feel its irregular. So in fact, we have always made qualitative judgments, involving values and cosmologies, in handling our quantities. Almost all the time these have happened automatically; where done self-consciously, they have been done for us. But they have been there. Now on this issue, as on so many others, we must be clear, aware, explicit, and self-conscious, but at least it is not a totally new phenomenon. Similarly, I think everything else we have been handling has been traditional in its origins but only very very new in the urgency of its consequences.

DISCUSSION COMMENTS

SINCLAIR: One thing I found possibly comforting in what you said was in coupling incompetence and tyranny. It seems to me that that is not the worst of all possible worlds; competency and tyranny are much worse.

J. SCHWARZ: I would like to raise a point that relates to the question of power. You say that the bureaucracies are, on the one hand, chained to the public, who perform risk analysis and control the hands of the system. On the other hand, you say that the bureaucracies are trying to assert power with it. You also mentioned that this power is connected with position and not with persons, whereas in earlier days power was connected to persons. But I think this is only appearance. If you look into the bureaucracy then I think, in fact, persons still have a certain amount of power and are asserting that power to support their own goals.

RAVETZ: There are two points to be addressed. One is that you have individuals who will push a whole bureaucracy in their direction and can change a high technology. And perhaps the example of this is Rickover who was very influential in getting his pressure water reactor design adopted as the basic civil reactor in the United States, simply because he was a very strong man. I think a great deal will also be done by people acting simply in a bureaucratic role. As you were talking I was thinking of myself acting as a teacher, and examiner. If I find a particular student who has not really been well treated in the exams, we cannot rock the boat too much, thus I might cover for my own problems.

Now you had a second point on risk. That if you perform a risk analysis then it is linked as the control. It is usually not the people promoting a project who talk most about the risks. It is those who oppose it. I make this point because it can go on the record that discussions of risk can be manipulated. We now see this happening in the UK in connection with the health and safety network. The people on the shop floor, particularly the trade unions people, have more power through the safety measures which are intended to guard their workmates from hazards. It can happen that they use that power in a traditional trade union way rather than in an objective risk control way. I even saw this happening when, as a representative of the public interest, I was on the genetic manipulation advisory group. I saw some great power struggles over trade union power in the framing of regulations for that group. It was quite clear that trade union members of this organization were going to claw as much power as they could for the trade union in those regulations. So, yes, you can say there is nothing sacred, even those who are subjected to a risk, if they are then given the chance to have some power in controlling it may use that power for other purposes.

KUNREUTHER: I wonder if we could turn our attention for a moment to some of the prescriptive aspects of your talk. I have two questions for you. One relates to countervailing power. Are there not possibilities for using power in a positive sense by having the forces that may see things differently coming together and debating or discussing the issues? The second question relates to where decision analysis plays a role given the fact that we now see that people may want to use data for their own interests. Can we begin to expose this self-interest in a way that is helpful for everyone?

RAVETZ: Yes, I can think of an analogy with trade union organizations a few generations back. My father was a trade union organizer, so I know a lot about trade unions, and that is about power, right? In the thirties America was largely an unorganized country, and there were some bitter struggles to get trade unions into the masses. And eventually union recognition was achieved, in a totally hostile environment. And there it was simply a question of how long could workers stay out on strike, until management gives way, gives them recognition or gives the wage increase. There was no recognized consensus, there was no rational dialogue. It was simply a question of naked power, economic power. As things settled down management began to accept the existence of trade unions and saw that they could benefit from their presence in various ways for regularizing the work force, having discipline. Then they had negotiations which developed an awareness of community of interest, an awareness of a common dialogue. All the time there were these obvious conflictual elements there. I remember somebody from one of the unions telling me of the way that they would get productivity figures for the firm and argue to the firm, "You can afford this," and the firm says, "Oh we cannot give you a nickel." Of course they did then play statistical games--was this a true measure, and so on. And it was a mixture of reason and power all the time. Now again, do you see the point?

KUNREUTHER: I would respond that management would come back with their own statistics and say, "here is where we come out on this. Now let us begin to try to put the two of these sets of figures together." Each group would be using their power and data to satisfy their own goals.

RAVETZ: Suppose you have a case where management comes in and labor comes in, each having had their own accountants. But in the last resort they get to the point where for bargaining purposes they can split the difference and go home. They need not agree who was right. That is irrelevant because the key thing is not the "truth"--who is right? Rather, the key thing is the "decision." Like the example that Ralph Keeney quoted, if you can convince your client that they made the wrong decision, they may want to argue that your analysis values this too high and this too low. That does not matter. It means shifting the ideal of the exercise from the advancement of knowledge to the arrival at decisions. The problem then solves itself.

ALAN MCDONALD (IIASA observer; USA): In referring to your last sentence, in which you mentioned shifting the object of the exercise from arriving at truth to coming to an agreement acceptable to both parties, the labor/management example may not be analogous to the problem of coming up with an acceptable site. For example, in the State of California, at one point Pacific Gas and Electric did negotiate with the Sierra Club concerning a nuclear power plant site, and the two came to an agreement. Then the Sierra Club membership changed their minds, voted in a new board of directors which reneged on the agreement, and that was the end of that. Do you have any suggestions as to how to make the institutional transition so that one could use the labor/management analogy more accurately?

RAVETZ: No. Maybe I am wrong but I could well imagine a particular institution being so discredited among those opposing its decisions that they would not really accept its good faith. Now maybe I have not followed California environmental politics in any detail, but in the UK, there is a lack of confidence between the two sides of an industry. People cannot really sit down and negotiate in good faith on issues. The "perfect" way is to state your position, show where it might be wrong, and list your key assumptions and indicate which you are ready to modify. You can do this only if you are not afraid that the other side will seize advantage. In other words, you can do this when it is not too conflictual, when the commitment to reaching a decision is much more important than getting the best advantage. The styles of resolving these conflicts varies enormously from one country to another. California is fascinating because it has a high level of awareness; but for this reason it may not be appropriate to generalize.

CLARENBURG: Let us turn to the question of new and large-scale technologies, where we cannot afford to learn from our mistakes. There are conflicting opinions on how to launch such projects. For example, an LNG siting project involves many conflicting sectors of our society--the economic sector, the planning sector, the risk sector, the environmental sector, and the public sector. If too much emphasis were given to, e.g. the environmental sector, the economy would be in danger. In the long run, this would also endanger employment. There are so many decision points that even an insider like myself cannot always tell when a decision was taken. Have you not been inconsistent by over simplifying things?

RAVETZ: Maybe. Your point about the shaping of a decision I agree with fully. Sometimes you have an exceptionally strong person who can actually mold the people around him in a bureaucracy. What makes this exceptional is that normally we think of such people as operating publicly in the political sphere, being visible, whereas, normally a bureaucracy is conservative, and rightly so. But occasionally you find a very big man who puts his stamp on a bureaucracy. The case of Rickover was perhaps illustrative, although it was dealing with a new technology in a new bureaucracy, so perhaps it was easier. As the big decisions grow it is more and more difficult for any particular force to prevail. The question is whether these countervailing powers suffice. I suspect they do, sometimes they do not.

I will give you a famous example from Scotland. There was a wonderful new town called Irvine. Long after it was built someone realized that across a narrow river was a factory that manufactures TNT/explosives. The ships go down this narrow river night and day, loaded with explosives. "No one" had noticed this factory when they built the town next to it. You could say that this proves your case in that the check-and-balance machinery was not good enough, and it certainly was not. I think it is possible for that sort of blunder to occur, and I believe if you look at the major technological investment decisions that have been taken elsewhere, you will see cases where it is in one bureaucracy that it emerges or is born. Yet mistakes are made, because the other bureaucracies, which are supposed to control it, are not effective enough. It is useful to distinguish between the promoting bureaucracy and the regulating bureaucracies. It is possible for those people to be asleep at the switch.

CLARENBURG: That is theoretical. How can you stay asleep when the whole population is falling over you? Hearing all the arguments which you have not really thought about while sleeping, that is impossible.

RAVETZ: Ah, you are now talking about Holland in this period.

CLARENBURG: Well, not only Holland. This is true everywhere where you have public participation.

RAVETZ: Okay, we are now living in a new period. I think until a very few years ago, these things would happen and could escape notice. I would conclude by saying that I do not see a better style of running technology except through a bureaucracy. And you need control. The point I want to make is that these acts are political and that if you do not have inputs from nonbureaucratic influences, from local groups, from special interest groups, then a very important check is lacking. This is where the incompetence comes in. Maybe it will never happen again, perhaps all of our engineers are now fully aware of geology and hydrology, pollutionology, and all these other "ologies." But until recently, they were not. A decision could grow, it could be crystallized, it could go forward until the local ornithologist would say, "My God, they are putting this there." Maybe this will change now, maybe in Holland, in particular.

SINCLAIR: I am glad you mentioned Holland, and I am glad you mentioned cultural differences because the people who want to speak are all Dutch–Cieraad, Reijnders and Schwarz.

CIERAAD: Perhaps I could add an example to what is happening in Holland. After the big flood in the 50s, the government quickly decided to close off the estuaries. Complete closure was thought to be the best solution, for reasons of safety. Yet, the environmentalists objected on the basis of the sea ecology. Eventually the last dam was redesigned to become ecologically acceptable, but only at a great cost. A movable barrier resulted; this barrier is currently under construction.

RAVETZ: In many ways this structure is the best we can do. The alternative is to have a type of command economy with a decision making political body that dominates everything including the bureaucracy. Let us say, a rapidly developing country like the Soviet Union in the early period, it decides that we will have this type of technology, we will have earth dams and steel mills and then everything will fit together as best as possible. Now that may be the best style without checks and balances in a very stressful, heroic period, because if you leave bureaucrats to decide these things then 20 years later you still have no heavy industry. But that is a different style with different costs and different benefits. Maybe one could say a truly popular style of decision making in high technology, that guaranteed that all the people were happy before you made a major installation, would also produce a particular style of development; a different style of development–like windmills.

REIJNDERS: How would you prescribe us to handle court cases in real life where probabilities are hard to quantify and understand?

RAVETZ: I do not know. We find that the numbers that we need to use for policy purposes are not exact, they are not hard. There are a number of judgements about them, and hardly anyone in the whole culture, even if he is a mathematician or engineer or politician, is competent in handling numbers this way. It is a dangerous state to be in. Our scientific education has made us culturally incompetent in talking and using quantities in these crucial problems. So I cannot solve the problem. I would like to see a book dealing with quantities in this more modern sort of way.

M. SCHWARZ: I want to come back to the decision process, and what was said abut the countervailing powers. You talked a lot about bureaucracies and how they behaved, and then the question arose whether there is a greater need for countervailing power. But if I look at the way the decision process has worked so far—looking, particularly with respect to the LNG project as we have done at IIASA--the more countervailing powers, the more conflict there seems to be; the more different positions are being taken, the more difficult it is to resolve the conflicts.

RAVETZ: There are two ways of looking at it. One is to say, that you have all of these local and ecological groups who will succeed in stopping technological progress and send us back to the stone age. The other way is to say that the development of these installations has been a sort of political oppression, and what looked desirable was, in fact, only the inability of the oppressed to do anything about it. Over these past 10 years, let us say, we have been going through a period where the oppressed are rising up and saying "no". This is always turbulent in the short run; it is always damaging. Take the trade union analogy. You can show that, in almost every case whenever workers go on strike, they are losing more money in lost wages than they can ever gain in the increase of what they are striking for. So in this sense strikes are always irrational. However, when there has been a genuine shift of power, and a genuine reduction on both sides, then you have a new sharing of power, a new sense of responsibility, a new dialogue. I am not an expert on LEG, but I think it is the sort of thing that we have to go through, because otherwise we could find ourselves with a whole lot of installations that were very, very dangerous.

M.SCHWARZ: Do you think decision analysis will uncover those aspects which are really political conflicts?

RAVETZ: Yes. In fact, Ralph Keeney has already given a couple of examples where you can show that on some reasonable payoff the costs and benefits are split very differently between groups. You may then start throwing in utility functions or weighting functions and say, "Well, how much do you worry about the American Indians taking off?", or, "How much do you worry about the asthmatics jogging in Los Angeles?" You may then have all sorts of considerations, but once the thing has been accepted as a fair picture, which is not the same thing as a scientific fact, then in that regard you are saying, "yes, someone is getting the costs and someone else is getting the benefits." What more do you want?

M. SCHWARZ: When you started I hoped you would indicate that often decision analysis will uncover the political conflict situation, it will in some cases cover up the conflicts.

RAVETZ: Of course. In the earlier period when the theme was being developed in a totally undisciplined way without a lot of collegial criticism, people simply got some accident statistics together and put exponents on numbers. Then it was a game that any number could play, and any number could have used. There was no real discipline in it. I think today, from what I see around this table, we do not play that game anymore. At least not the people in this room. It is now used as part of a negotiation rather than as part of propaganda campaigns. You can still disagree. You can still use it to mystify if you can get away from it. But it is no longer simply a case of valium from him and amphetamine from him. The thing is maturer; it changes character.

MEHTA: Ever since I have read one or two works by Jerry Ravetz, I would always agree with what he says, although I do not necessarily always understand it. But I would like to clarify one point where I think there seems to be a little inconsistency. He talked about the incompetence and the tyranny and, therefore, presumably a need to control it or at least to do something about it. At the same time he goes on to discuss the inadequacy of the mathematical science as a basis for safety judgment, I see some conflict here, in that, unless we develop and define the mathematical models and the risk analysis, there will be all the more scope for the mis-use of power. Do you see this as a conflict?

RAVETZ: Well I guess that the most urgent thing is to develop an appreciation of handling inexact quantities. Until you have that, more refined mathematical tools would only lead to a higher level of nonsense. Whereas, I think if one knows how to use them with good craft skills, given their inexactness, tempered by political prudence when they are introduced into the debate, then they can make a contribution.

THE ROLE OF RISK ASSESSMENT IN FACILITY SITING: AN EXAMPLE FROM CALIFORNIA

John W. Lathrop
IIASA

I. INTRODUCTION[1]

As the number and scale of energy facilities increase, government agencies are faced with more and more difficult decisions involving the management of societal risk. Since the risks can be complex and not well understood, risk management decisions can be extremely difficult to make. It would seem, then, that there should be an important role for formal analyses in assessing risks to aid those decisions. This paper explores that role in the context of the attempted siting of a Liquefied Natural Gas (LNG) facility on the California coast. While the first site application was filed in 1973, as of this writing (October 1980) no site has been approved. The story of those eight years, a fascinating case study in societal risk management, has been told and analyzed with insight by two of the participants in the process: William Ahern (1980a,b) and Randolph Deutsch (1980). This paper concentrates on one aspect of one episode in that siting process, taking the point of view of the frustrated decision analyst, trying to understand the role his tools play--and could play--in the political process of siting. After investigating that role, the paper concludes with some brief and very general recommendations as to what research is called for to make those tools more useful.

[1]The research reported in this paper is supported by the Bundesministerium für Forschung und Technologie, F.R.G., contract no. 321/7591/RGB 8001. While support for this work is gratefully acknowledged, the views expressed are the author's own, and are not necessarily shared by the sponsor.

In early 1977, state and federal regulatory agencies were favoring an LNG terminal site at Oxnard, California. As part of the site approval procedure, assessments of the risks to surrounding areas due to the LNG terminal had been done by the federal regulatory staff (Federal Power Commission, FPC),[2] and by consultants hired by the gas company (Science Applications, Inc., SAI). Both risk assessments estimated the probabilities of each of many possible accidents and derived from them various measures of the risk in probabilistic terms, such as expected numbers of fatalities, probability of fatality per exposed person per year, etc. The implicit goal of both of these assessments was to measure the risk in summary terms that could assist in the determination of whether or not the risk was low enough for the site to be acceptable. Both assessments indicated that the LNG risks to Oxnard were extremely low or negligible (SAI 1975; FPC 1976). The appropriate federal agency deemed the Oxnard terminal acceptably safe, and approved it in December 1977. Considering all of these events, things seemed to be moving smoothly toward approval for the Oxnard terminal. However, the city of Oxnard had commissioned another consulting firm, Socio-Economic Systems, Inc. (SES) to do an environmental impact report. As part of that effort, SES did its own risk assessment, which combined assumptions and model results from SAI, FPC, and U.S. Coast Guard studies to calculate about 5.7 expected annual fatalities as a summary measure of the risk of the LNG terminal (SES 1976). This was about 380 times higher than the corresponding estimate by SAI. However, according to Ahern (1980a) the politically more important part of the SES report was a set of descriptions of several deterministic worst case scenarios, with flammable vapor clouds covering up to 70,000 people, presented without estimated probabilities of occurrence. The publication of those scenarios "electrified opposition to the terminal," to quote Ahern.

In the face of opposition to the terminal based on concern for safety, the California state legislature passed the LNG Terminal Act of 1977 (S.B.1081, September), which excluded the Oxnard site. That bill may have passed with or without the SES worst case scenarios, but the fact remains that the SAI and FPC probabilistic risk assessments did not help the gas company or the regulatory agencies gauge the actual political acceptability of the Oxnard site. The assessments could have been intended for any of several purposes, among them two in particular: to warn the company away from a site where it would be imposing politically unacceptable risk, or to convince all appropriate government agencies that the site was acceptably safe. Measured against either of these two purposes, the SAI and FPC risk assessments failed. This paper presents and discusses four very general reasons for this failure:

[2]The FPC staff more or less became the Federal Energy Regulatory Commission (FERC) staff in the course of the creation of the Department of Energy in 1977. Their work will be referred to as the FPC assessment throughout this paper.

- differences in definition and evaluation of risk
- differences in approaches to risk management
- the nature of the role of analysis in the political process,
- the nature of the political process itself

The last section of the paper summarizes the lessons that can be learned from the discussions of these points, bringing them together in the form of very brief descriptions of the most promising areas for research directed at improving the usefulness of risk assessment in the political siting process.

II. DIFFERENCES IN DEFINITION AND EVALUATION OF RISK

Given the extent of controversy surrounding questions of societal risk, it seems odd that the debate goes on without a clear definition of what risk is. In fact, this section suggests that differences in definitions of risk are basic parts of the problem of managing societal risk.

A. FOCUSING THE DISCUSSION

An LNG siting problem, as discussed here, consists of two interdependent decisions: whether or not to have the LNG project, and if so, where to site the plant(s). A disinterested observer might view these decisions as involving the consideration of very uncertain benefits and losses, all viewed in relation to the alternative action (pipeline, oil, coal, nuclear, conservation, other site). The LNG plant could cause an uncertain reduction in the number and severity of supply interruptions, an uncertain change in the finances of the utility and its customers, an uncertain loss of flora and fauna, an uncertain degradation in people's enjoyment of the coast, an uncertain reduction in air pollution health effects, and an uncertain increase in accident-related loss of life and limb. While these statements suggest directions of LNG plant effects (reduction, increase, etc.), those directions depend on what alternative is assumed to take the place of the LNG project if it is not permitted, and on assumptions made in the related analyses. While it would be interesting to consider all of the factors listed, this paper focuses on health effects, including air pollution effects and accident-related loss of life and limb, factors central to the example given in the introduction. The word "risk" is used to denote some measure of those uncertain losses, reflecting the typical use of the word in such terms as risk assessment and societal risk. Even with this focus, uncertain health effects are many-dimensional things, so that any definition of risk must involve assumptions concerning how those losses are to be evaluated. That is the source of a key aspect of the societal risk management problem: There are two different types of definitions of risk, which arise from two basically different perspectives on risk, technical and societal. These two perspectives can lead to substantially different evaluations of the acceptability of the risk resulting from an LNG alternative.

B. TECHNICAL PERSPECTIVE

From the technical perspective, risk is some probability distribution over sets of health effects. For example, in one paper Keeney (1980a) defines the risk of a technology as a probability distribution over sets of probabilities $\{ p_i, i=1, \cdots, N \}$, each set denoted in short as $\{ p_i \}$, where p_i is the probability that the ith individual of a group of N individuals will die due to the technology before the end of the next time period. The probability sets $\{ p_i \}$ are constructed in such a way that within each set, each probability is independent of any other. The probability distribution over those sets is required to represent probabilistic dependencies between the fatalities. For example, in the LNG case the probability distribution over sets $\{ p_i \}$ could be essentially the probability distribution over accidents. To illustrate, suppose only one accident was possible for an LNG facility, that accident could occur with an annual probability of 10^{-7}, and it would expose each of the nearest 100 people to a very high fatality risk of 80%. While the possibility of such an accident results in an annual mortality probability of $.8 \cdot 10^{-7}$ for each of those people, that number alone does not reflect the fact that the fatalities would occur in one large accident of about 70 to 90 fatalities, if any occur at all. The probability distribution over sets $\{ p_i \}$ can be used to calculate both the probability of fatality per exposed person per year and the potential for high-fatality accidents. Past risk assessments have used these and other summary measures of that probability distribution. The SAI and FPC studies referred to earlier used among other measures the probability of fatality per exposed person per year, an index convenient for comparing individual risks from LNG to risks from other sources. In the Reactor Safety Study ("Rasmussen report"), the risk of nuclear power was represented by a reverse cumulative probability distribution over numbers of fatalities per year per reference reactor (USNRC 1975). One can read directly from a graph of that distribution the annual probability that the number of fatalities will exceed 10, will exceed 100, will exceed 1000, etc. It follows that such a distribution, often referred to as a Rasmussen curve, very directly indicates the potential for catastrophe. The same type of distribution has been used with LNG risk assessments (Hazelwood and Philipson 1977). Some risk assessments go one step further and reduce the distribution to the expected number of fatalities, a measure reported in the FPC and SES studies (see also Paté 1978).

C. SOCIETAL PERSPECTIVE

In contrast to the fairly straightforward technical-perspective risk measures listed above, extensive psychological research in the field of risk perception has suggested many more aspects to be included in a measure of risk that would be more sensitive to the concerns of political and societal processes (Fischhoff et al. 1978; Linnerooth 1978; Otway and Pahner 1976). Some of these aspects are listed and briefly discussed here as a way of describing risk from a societal perspective. This section is not intended to cover these aspects in any detail, as most of them have been treated at length in the cited papers. The aspects are listed roughly in order from the most easily adapted to a simple technical index to the most difficult.

1. Possibility of catastrophe

Some technologies cause fatalities that occur one at a time, scattered widely over a geographic area. An example would be the fatalities due to air pollution caused by burning substitutes for natural gas. While those effects are "spread out" over space and time, the fatalities from a major LNG accident would be "bunched" into a catastrophe at one place and time. That bunching can be very important for how society evaluates the risk. While the Keeney and Rasmussen measures reflect bunching, or possibility of catastrophe, the other technical-perspective measures listed above, probability of fatality per exposed person per year and expected number of fatalities, do not.

2. Inequity of impacts

An LNG plant that exposes people in its immediate neighborhood to a risk for the benefit of all Californians is a case where inequity is important. The air pollution due to a lack of natural gas would be a risk spread more widely over the benefiting population, and so would be more spatially equitable. A risk that may seem acceptable by an aggregate measure, such as expected number of fatalities, may not be politically acceptable if it is inequitably distributed.

3. Degree of control

This aspect is a much more general version of the voluntary/involuntary distinction made by Starr (1969). The central concept here is the level of participation of each potential impactee in each of two decisions: to expose himself to the risk, and to deploy the technology in the first place. Starr presented evidence which he interpreted as indicating that society has a much higher threshold of acceptability for risks involving voluntary exposure than for risks incurred involuntarily. Arguments against that hypothesis have appeared in the literature, most recently in the paper by Slovic, Fischhoff and Lichtenstein (1980), which concludes that apparent aversion to involuntary risk can be better explained by the higher potential for catastrophe and inequity that often accompany that type of risk. However, in another paper the same first two authors stress the importance of public participation in the second of the two decisions listed above, concerning the deployment of the technology (Slovic and Fischhoff 1979).

4. Attribution

This is an important aspect of societal reaction to a risk that is often overlooked because of the cause-specific way risk assessments are performed. There is no doubt as to the cause when a person has been injured or killed by an LNG accident. On the other hand, it may not even occur to someone when an elderly relative dies that he may have lived longer if there had been less air pollution. Beyond that, it would be impossible to attribute any death in particular to the increment in air pollution caused by a low share of natural gas in the energy mix. It may not seem reasonable in a narrowly prescriptive sense to evaluate easily-attributed health effects any differently than more subtly-linked health effects. However any more broad, strategic effort to assess the political acceptability of a project should take attributability into account.

5. Non- decision comparisons

The search for criteria for acceptable risk often falls back on comparisons not involved in actual decisions. For example, comparisons are often made between LNG or nuclear risk and risk of disease, or risk of the rest of the fuel cycle, or risk of smoking an extra cigarette. Yet very few people choose between living near an LNG plant and exposure to risk of disease. The latter risk is always there, as is the risk of the rest of the fuel cycle, so the LNG risk adds to it. Perhaps even fewer people choose between living near an LNG plant and smoking an extra cigarette, though that decision involves some interesting interactions. Yet the use of such benchmarks in evaluating societal risk may be helpful in placing assessments of risks in more meaningful terms than probabilistic measures (Lichtenstein et al. 1978).

6. Non- probabilistic evaluation

Perhaps the most serious mismatch between technical and societal perspectives lies in the societal sensitivity to descriptions of severe outcomes with no regard for the estimated probability for those outcomes. This aspect may have been a key one in the rejection of the Oxnard site mentioned earlier. Worst case scenarios, with uncalculated but extremely low probabilities, seemed to be effective in furthering opposition to the site. While it may be tempting to consider this an example of faulty information processing, of misuse of technical information, in fact there are reasonable justifications for this aspect of risk evaluation: doubt in the ability of probabilistic assessments to avoid underestimating probabilities of accidents, sensitivity to the feeling of dread that could accompany living in the shadow of a vividly described catastrophe, or desire for a resilient social system. However, this aspect of risk evaluation is directly incompatible with the probabilistic orientation of any of the technical-perspective risk measures listed above. One difficulty with any prescriptive evaluation incorporating this aspect is that the most severe outcome described is dependent upon the imagination and motivation of the analyst. Yet once again, any attempt to gauge the political acceptability of a risk should take this aspect into account.

7. Indirect effects

Some aspects of a technology having little to do with possible health effects may have a great deal to do with a societal evaluation of risk. Those aspects include the degree of centralization, how closely a new technology is linked with a high-consumption lifestyle, etc. While these aspects seem far removed from evaluating the risk to life and limb of LNG, they should be included in any effort to understand possible opposition to an LNG site.

D. IMPLICATIONS OF THE TWO PERSPECTIVES

The difference between the two perspectives on risk described above may have very direct relevance for the role of a risk assessment in a political risk management process. This is illustrated by the LNG siting example given in the introduction. The SAI and FPC risk assessments could be viewed as adopting the technical perspective. While parts of the SES assessment adopted that same technical perspective, other parts included worst case scenarios that caught the attention of people with a societal perspective. While the gas company and regulatory agencies were planning on the basis of the technical perspective of risk, the political process they had to deal with was quite naturally sensitive to the societal perspective. The result: probabilistic risk assessments were not effective in guiding the gas company and regulators, nor were those assessments persuasive in the political process. From the other point of view, the political process was not aided by the analytic effort that went into the SAI and FPC assessments. Clearly, no party was served by the mismatch between the technical perspectives of the probabilistic risk assessments and the societal perspective of the political process. Just as clearly, if risk assessments are to serve the applicant seeking to site a hazardous facility and the political process seeking to manage the resulting risk, then either the assessments should adopt more of a societal perspective of risk, or the political process should adapt itself to assessing risks from a more technical perspective.

As the previous paragraphs have made clear, there are many more aspects to the evaluation of societal risk than summary measures of probability distributions on health effects. The limited measures of past probabilistic risk assessments make it easy to suggest that adding more evaluation dimensions to an assessment will then provide more useful guidance to the parties in the siting process. In fact, decision analysts have proposed significant and interesting ways to expand probabilistic risk assessments to explicitly incorporate dimensions that represent societal concerns (Bodily 1980; Keeney 1980 a,b). These approaches are based on multiattribute utility analysis, which can generate evaluation functions that not only represent value tradeoffs between several dimensions, but also represent attitudes toward uncertainty (Keeney and Raiffa 1976). Such functions seem to hold great promise for bringing more of a societal perspective to risk assessments, making those assessments more useful and used. However, as the next sections demonstrate, there are more fundamental problems in the interface between risk assessment and the political process than a lack of dimensions.

III. DIFFERENCES IN APPROACHES TO RISK MANAGEMENT

Beyond differences in how risks are evaluated, political organizations cope with the uncertainties inherent in risk management in ways very different from that assumed in typical risk assessments. There are two types of uncertainty involved. First, there is uncertainty in the outcome of any action since the future is full of unknowns, accidents may or may not happen, physical processes are not completely understood, etc. Second, there is uncertainty in the results of any analysis. From a particularly narrow analytic point of view, looking only at a decision to be made immediately, there is no operational difference between these two uncertainties. But from a more strategic point of view, the second uncertainty reflects how likely the results of an analysis are to be subject to argument, or worse yet, how likely those results are to change. The possibility of analytic results changing within a few years gives very reasonable pause to a government agency about to commit resources to an action with effects spanning decades (e.g., setting a regulation or allowing a plant to be built). The next two sections explore how the analytic and political communities cope with these two uncertainties.

A. THE TECHNICAL APPROACH

Expected numbers of health effects is a risk measure that does not reflect outcome uncertainty, though it is sometimes reported with an error band indicating analysis uncertainty. The other technical-perspective risk measures reported above explicitly account for at least some aspects of outcome uncertainty, though often the analytic uncertainty is either not reported or is not clearly reported along with the risk measures, as was the case with the SAI and FPC assessments. Sometimes Rasmussen curves are reported with error bands reflecting analytic uncertainty, as in Hazelwood and Philipson (1977). In many cases analytic uncertainty is coped with by adopting conservative assumptions, then maintaining or implying that the reported risk measure is at the conservative end of the analytic uncertainty error bar. The fact that the SAI and FPC assessments differ in many of their measures, while both claim conservative assumptions, illustrates that there can be differences of opinion regarding what is an appropriate conservative set of assumptions.

While the technical-perspective risk measures discussed so far report uncertainty to varying degrees, evaluation is limited to observing how small the probabilities are, perhaps in non-decision comparisons as described above. In contrast, the decision analytic expansions to the technical perspective discussed before (Keeney 1980b; Bodily 1980) employ expected utility theory (von Neumann and Morgenstern 1947), which incorporates attitude toward outcome uncertainty in the risk measure itself. In this type of approach, the risk measure is the expectation of an index (utility) that is a nonlinear function of the outcome measures. On any one dimension, then, if the utility function is concave downward, the expected utility risk measure will discount the value of an option with high outcome uncertainty relative to another option with the same expected outcome but less uncertainty. In such an approach, analysis uncertainty can be gauged by a sensitivity analysis which adds error bars to the risk measure.

In the technical approach, then, outcome uncertainty is reflected in all but one of the risk measures, and attitude toward outcome uncertainty is incorporated within the expected utility risk measures. Analytic uncertainty is represented, when it is at all, by error bars or bands around any of the measures, or is dismissed by maintaining or implying that the reported measure is at the conservative end of the error bar. It follows that each technical approach to coping with uncertainty is based on one of two assumptions. The approaches not based on expected utility assume that once outcome and analytic uncertainties are measured and presented, the political process will know what to do with them. The expected utility approach incorporates attitude toward outcome uncertainty directly in the risk measure, assuming that the political process will want to trade off outcome uncertainty with expected outcomes in the way prescribed by von Neumann and Morgenstern (1947).

B. THE POLITICAL APPROACH

The political process, to the extent that one can generalize, often takes a markedly different approach to coping with uncertainty than that assumed by the expected utility risk analyst. Three brief examples illustrate this. When the Office of Technology Assessment did a study on LNG in 1977, it concluded that, in the face of the large analytic uncertainties, "... decisions about LNG systems should be made on the basis of nonquantitative approaches... " (USOTA 1977). When the FPC staff assessed the risks of two California LNG sites (Oxnard and Point Conception), it found the two resulted in different but very low risks. It decided that both sites resulted in an acceptable level of risk, then dropped risk as a factor and favored the more risky Oxnard site on other grounds. When the California state legislature drafted the LNG Terminal Act of 1977, it set a stringent remote siting constraint intended to preclude a worst case scenario anything like the ones SES published concerning Oxnard.

All of the above examples point to the same conclusion: these political decision-making processes do not take the probabilistic perspective of the risk analyst, are not ready to incorporate uncertainty into risk evaluation in any way resembling the expected utility approach, and refuse to explicitly trade off risk to life and limb against any other dimension. It is misleading to refer to a political process as risk averse in the expected utility sense, since the thinking evidenced in the processes cited above has very little to do with the expected utility model. The thinking is basically non-probabilistic. In reference to the California remote siting provision and the SES worst cases for Oxnard, one legislative staff member stressed that the California legislature could not allow a site that could kill 40,000 people. The remote siting provision was a constraint used to avoid any explicit trading off of safety with environmental quality, cost, etc. The FPC staff employed similar reasoning in determining that the risk was less than some level, then dropping it from consideration. In each case, the setting of a constraint was effectively an heuristic employed to simplify a difficult decision. Of course, the level at which the constraint was set involved implicit tradeoffs between safety, environment, and cost, as well as judgments concerning the nature of sites available on the California coast, but those tradeoffs and judgments were never considered in an explicit manner.

As with any heuristic, the remote siting constraint imposed a probable cost. Ahern, representing himself and not his agency, has maintained that it almost certainly precluded sites that would be deemed more desirable by any reasonable evaluation (personal communication 1979). More generally, a desire to preclude the possibility of a disaster, no matter how improbable, can lead to decisions that impose financial and environmental costs. Ahern (1980b) describes two cases of this in recent California decisions.

IV. THE ROLE OF ANALYSIS IN THE POLITICAL PROCESS

It is interesting to consider various modes of risk assessment on their own merits. But no analysis exists in a vacuum. Its effectiveness depends critically on the process of which it is a part. Three critical features of that process which can cause problems for the use of risk assessments are briefly reviewed here. We first consider the disaggregated nature of the political process, then examine the two typical ways in which analyses are used in siting procedures: in drafting legislation or regulations, and in hearings.

A. DISAGGREGATED NATURE OF THE PROCESS

The most serious problem in the use of a decision analytic siting evaluation model, such as the one proposed by Keeney (1980c), is that the decision structure assumed by the model does not match the institutional structure making the siting decision. For example, the most basic assumption made by the above model is that there is some single, self-aware process somewhere making tradeoffs between conflicting objectives, such as between safety, cost, and environmental quality. In fact, the actual process may be such that those tradeoffs are not made by any identifiable agency, but are made in the interaction between several agencies and several societal interest groups, with each agency or group only looking at a part of the problem.

The California LNG siting process is a good example of disaggregation. Three agencies were centrally involved in the state level decision making: the state legislature, the California Public Utilities Commission (CPUC) and the California Coastal Commission (CCC). The state legislature set up the siting process, including a single-agency licensing provision intended to ensure a timely decision, and a remote siting requirement to ensure public safety. As part of that process, the CCC ranked alternative sites, considering primarily environmental quality subject to the remote siting constraint. Then the CPUC selected a site, not necessarily the site ranked highest by the CCC, considering primarily cost and how quickly the site could be developed, relative to the state's need for LNG. The major relevant objectives were cost, safety, environmental quality, and need for LNG as a function of time. Each agency would maintain that it considered all factors, yet the mandates of each are such that each paid special attention to a different subset of those objectives. Complicating the picture still further, two agencies within the federal government were also part of the process: one looking at all of the major objectives the other attending to questions of national import policy. None of these state and federal agencies is a decision-maker in isolation. Each conducts some process of hearings, meetings, testimony or voting, a process that provides for the representation of the various groups that stand to gain or lose by the proposed project. Those groups include the applicant, neighborhood groups, and interest groups such as labor and the environmental coalitions. Each group is in effect another decision maker in the process, presenting particular arguments to each of the agencies, arguments based on each group's unique value tradeoffs and projected impacts. Add to all this the fact that the decisions of all government agencies are subject to judicial review by state or federal courts, and it becomes very hard to identify any single self-aware decision-making process where all the tradeoffs are made. To be sure, the overall process results in some decision, which can be analyzed as being consistent with particular implicit tradeoffs, but any similarity between tradeoffs consciously made and those inferred is likely to be simply fortuitous. It is not clear where a decision analytic evaluation model would fit into such a process, whose tradeoffs should be used to set the parameters, or even to whom the analysis should be delivered.

B. ROLE OF ANALYSIS IN FORMING SITING LEGISLATION, REGULATION

One of the observed roles of analysis in siting procedures is in guiding the drafting of the relevant legislation and regulations. Consider, once again, the California LNG Terminal Act. That act established several interesting aspects of the siting process, but here we will focus on the remote siting constraint mentioned above. While it could be described as an heuristic, it is set in very technical language (at most 10 people per square mile within one mile, at most 60 per square mile within four miles), with numbers that were based on analyses. A decision analyst would be inclined to measure the probabilistic costs and benefits of each of various levels of the remoteness constraint, and pick the most favorable. But in this case, while the legislative staff had an entire range of analyses to look at, from each of several different studies and experts, none of them assessed in any direct way the costs and benefits of any level of constraint. Instead, each analysis indicated the maximum distance a flammable methane cloud could travel from an LNG plant. The state of the art in understanding the physical process was weak enough that any of a number of acceptable sets of assumptions could drive an analysis to any of a number of results. In fact the results of the analysis varied from 1 mile to 50 miles for maximum cloud distances. It was not clear which set of assumptions was "neutral", or which was most appropriate for use in drafting legislation. No analysis was used in turn to aggregate this range of analyses into summary measures to guide the setting of the remote siting constraint. The drafting of the legislation was a matter of examining the range of analyses, then making direct intuitive judgments as to the most appropriate constraint. In this case, then, analyses were used in the drafting of legislation, but only for very low-level inputs that were not very directly related to the costs and benefits involved in the actual decision.

C. ROLE OF ANALYSIS IN HEARINGS

The second observed role of analysis in siting procedures is in presenting the various cases before a hearing process. There have been several hearings in the California LNG siting process, ranging from quasi-judicial to legislative in nature, at the local, state, and national levels. The hearings considered every aspect from energy need to safety to cost to the relative merits of the various sites. Take as one example the CPUC hearings to determine the need for LNG in California. Several different agencies presented testimony, each supported by an analysis of a slightly different character, as described by Ahern (1980b). But once again, as in the previous subsection, the several analyses showed several different conclusions, and they were aggregated into the CPUC decision to approve the terminal without any traceable analytic link back to the testimony analyses.

D. SECTION CONCLUSIONS

The key feature in each of the previous two subsections is that in the California siting example, there was not *an* analysis, but many analyses, all suspected of one bias or another, and those analyses were aggregated into risk management decisions in a non-analytic way. There did not seem to be a single objective risk, but rather more than one analysis indirectly assessing risk. There are analytic tools that could be used to combine several analyses into a single source of advice for the decision making process. However, those tools, based on Bayesian statistical inference, would require subjective judgments that would explicitly set the weight given to each analysis, or to each set of assumptions adopted. While this would be a promising avenue to pursue, it may not be politically feasible to collect those judgments. Beyond that, it may not be seen as appropriate to extend analysis to that level, as it would involve political considerations that are seen as properly treated only in legislative and hearing processes.

V. CONCLUSIONS: FUTURE RESEARCH DIRECTIONS

The previous sections of this paper have presented basic problems with the interface between risk assessments and the political siting process. Those problems involve differences in how risk is defined and evaluated, how uncertainty is coped with, how analyses are used in the political process, and the nature of the political process itself. While the discussions of those problems are interesting in and of themselves, they also provide insight into the most promising directions for research to improve the usefulness of risk assessment in the political risk management process. To begin with, there are of course two sides to the interface between risk assessments and the political risk management process. However, the problematic features on the political side of the interface seem either extremely difficult to change or not desirable to change. It seems most appropriate, then, to address the problematic features on the assessment side of the interface. A review of the previous sections indicates the most promising areas for improvement:

- Extend the scope of risk evaluation measures to account as much as possible for societal concerns.

Section II described basic differences in the technical and societal perspectives on risk, and the implications of those differences. Risk assessments typically adopt a technical perspective, and so provide very straightforward, single-number evaluations of risk that do not incorporate societal concerns very well. Political processes are sensitive to the societal perspective, but research describing that perspective is not oriented toward evaluations of risk that provide clear guidance for risk management decisions. Future research should seek to close that gap by developing hybrid risk evaluation aids that are sensitive to societal concerns, yet provide clear risk management decision aids. Work has begun in that direction (Bodily 1980; Keeney 1980 a,b), but should be extended.

- Develop risk management decision aids that are compatible with the essentially non-probabilistic orientation of the political decision maker.

Section III described basic differences in the technical and political approaches to risk management. The most significant difference is the essentially non-probabilistic orientation of many political decisions. That is very problematic for most risk assessments, which tend to be probabilistic in nature. Yet if risk assessments are to be useful, ways must be found for their results to be expressed in a language that the political decision maker can understand.

- Examine analytic techniques for aggregating the results of several different analyses, and select and adapt the most promising ones for use in the political process.

Section IV identified the need for developing analytic tools with which to aggregate results of analyses, then went on to enumerate the problems involved in implementing those tools. Yet not enough is known at this time to assess the feasibility of those tools. That feasibility must be tested by applying the most promising aggregation techniques in actual case studies.

Certainly, none of the research tasks described here is easy. However, the potential usefulness of improvements in any of the areas would justify the research effort many times over.

REFERENCES

Ahern, W. 1980a. "California Meets the LNG Terminal", *Coastal Zone Management Journal* 7, p. 185-221.

Ahern, W. 1980b. "The Role of Technical Analyses in California Energy Siting Decisions". Paper prepared for the LEG Case Study Task Force Meeting, IIASA, Laxenburg, Austria, September.

Bodily, S.E. 1980. "Analysis of Risk to Life and Limb", *Operations Research* 28(1), Jan.-Feb.

Deutsch, R.W. 1980. "Siting an LNG Facility in California: The Regulatory Framework and the Factors Involved in the Decision Making Process". Paper prepared for the LEG Task force Meeting, IIASA, Laxenburg, Austria. September.

Fischhoff, B., P. Slovic, S. Lichtenstein, et al. 1978. "How Safe is Safe Enough? A Psychometric Study", *Policy Sciences* 8.

FPC. 1976. Pacific Indonesia Project, Final Environmental Impact Statement, Federal Power Commission. December.

Hazelwood, R.N. and L.L. Philipson. 1977. Survey of LNG Risk Assessment, Report for the California Public Utilities Commission,Socio-Economic Systems, Inc., Los Angeles.

Keeney, R. L. 1980a. "Evaluating Alternatives Involving Potential Fatalities", *Operations Research*, 28 (1), Jan.-Feb.

Keeney, R. L. 1980b. "Equity and Public Risk", *Operations Research* 28(3), May-June.

Keeney, R. L. 1980c. *Siting Energy Facilities*, New York: Academic Press (in press).

Keeney, R. L. and H. Raiffa. 1976. *Decisions with Multiple Objectives*, New York: Wiley and Sons.

Kunreuther, H. 1980. "Societal Decision Making for Low Probability Events: Descriptive and Prescriptive Aspects", (forthcoming IIASA working paper).

Lichtenstein, S., P. Slovic, B. Fischhoff et al. 1978. "Judged Frequency of Lethal Events", *Journal of Experimental Psychology: Human Learning and Memory*, 4 (6).

Linnerooth, J. 1978. "Reevaluating the Value of Life: Practical Considerations", invited paper presented at ORSA/TIMS Conference, Los Angeles, November.

Otway, H. J. and P.D. Pahner. 1976. "Risk Assessment", *Futures*, 8 (2).

Paté, M.-E. 1978. "Public Policy in Earthquake Effects Mitigation", Technical Report 30, Blume Earthquake Engineering Center, Stanford.

SAI. 1975. LNG Terminal Risk Assessment Study for Oxnard, California. Prepared for Western LNG Terminal Company, SAI-75-615-LJ. La Jolla, California: Science Applications, Inc.

SES 1976. Environmental Impact Report for the Proposed Oxnard LNG Facilities, Socio-Economic Systems, Inc., Los Angeles, California. September.

Slovic, P. and B. Fischhoff. 1979. "How Safe is Safe Enough? Determinants of Perceived and Acceptable Risk", in L. Gould and C. A. Walker (Eds.), *Too Hot to Handle: Social and Policy Issues in the Management of Radioactive Wastes*, New Haven: Yale University Press.

Slovic, P., B. Fischhoff and S. Lichtenstein. 1980. "Perceived Risk", in R. C. Schwing and W. A. Albers (Eds.), *Societal Risk Assessment: How Safe is Safe Enough?* New York: Plenum Press.

Starr, C. 1969. "Social Benefit Versus Technological Risk", *Science*, 165: 1232-1238.

USNRC. 1975. *Reactor Safety Study*, ("Rasmussen Report"), WASH-1400, Washington, D.C.: U.S. Nuclear Regulatory Commission.

USOTA. 1977. Transportation of Liquefied Natural Gas, Washington, D.C.: U.S. Office of Technology Assessment.

von Neumann, J. and O. Morgenstern. 1947. *Theory of Games and Economic Behavior*, Princeton: Princeton University Press.

DISCUSSION COMMENTS

OTWAY: What John presented is very interesting; but his analysis is, of necessity, far too simple to have anything to do with the problem; you have to work with a finite number of dimensions and a finite number of groups. For example, one "societal group" that he includes in his analysis is in reality perhaps 10 or 20 groups; in addition, the dimensions that each group uses to characterize the problem are completely different from those that other groups utilize. The difference between the real situation and what can be analyzed is so great.

LATHROP: I agree that there is a problem in modeling such a process. Rather, I would try to be creative and determine what can be done with each of the parties in the process, what tools can be given to each of them, so that each one can make sure it is pursuing its interests in a consistent way. This might help in negotiations between the parties.

DEUTSCH: An LNG project starts in a foreign country and terminates in the receiving country, and there is a lot in between concerning business and policy decisions. My question is "Have you analyzed an *entire* LNG decision?", or have you fallen into the trap of analyzing only a small part of the project, in particular that part on which the political and societal interests are focusing, mainly the LNG receiving terminal?

LATHROP: Yes, we have fallen into the trap of analyzing only a part of the project. We are focusing on import siting questions since this part of the problem seems to be the most relevant to our research interests as specified in my presentation. In our experience, negotiating the contract with the export country, siting the export plant, and all those other segments of the project do not involve problems relevant to our research interests.

THE ENERGY POLICY, SITUATION AND
L.E.G. SITING IN THE NETHERLANDS

J.J. Schwarz
Staffgroup Staffgroup Surveys TNO

Introduction

In the beginning of the seventies it became clear in Holland that the sell-out of Dutch Natural Gas (NG) to other European Community (EC) countries must be stopped, because nuclear power could not be introduced with the pace which was expected in the mid-sixties. After the energy crisis of 1973 the Dutch government, like other industrialized countries, started to worry about future energy supplies in relation to the expected increase in the energy consumption. This motivated the authorities and interest groups to formulate a policy in which the future energy supply was ensured. These policies are straining the siting procedures concerning safety, environmental protection and physical planning.

The Energy Policy in the Netherlands

Since World War II the energy situation in the Netherlands is changed dramatically, like in other industrialized countries. In 1946, for instance the total energy consumption was covered for 84% by coal and 16% by oil. Until 1963 the absolute amount of coal did not rise but the share of oil raised to 54%. After that time the production of the Slochteren gas field ($\pm$ 2000.$10^9 m^3$) in Groningen started. In 1972, about nine years after the introduction of natural gas (NG) the picture was: coal 5%; natural gas 46%, and oil 49%. In 1975, the share of oil dropped to 37% and the use of natural gas rose to 57%. Figure 1 gives an impression of these changes in consumption.

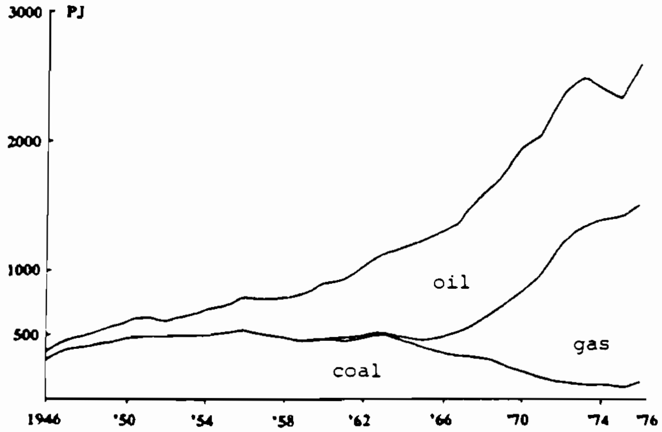


Figure 1. The post-war energy consumption in the Netherlands.
Source: Energie Spectrum '79-4.

In 1974, the government published the first policy paper on the future energy situation in the Netherlands. In this paper the following aims were indicated:

-- savings on the whole range of energy consumption,
-- a strategic natural gas reserve,
-- less dependency from other countries for the energy supply,
-- substitution of oil by other energy sources.

The government expected that the share of natural gas in the energy supply would fall from 50% in 1980, to 24% in 1985. At the same time the importation of NG would increase from ±0% in the seventies to ±30% in 1985. Another substitution would be the increased use of coal (3 à 4 millions of tons/year) for electric generation and on the long term for coal gasification (SNG). Recently a new paper of the government was published on this matter. The Dutch energy policy explained in it will be based on two aims, namely: energy savings and a divergent energy mix.

To reach the first aim, the government has formulated a programme which indicates that the saving of energy is of growing importance. Dependent of the expected annual economic growth (2-3%), the government aims at total savings of 10% in 1985, about 20% in 1990, increasing to 30% in 2000, all compared with the amount of energy consumed in 1977. Figure 2 gives an impression of the future energy consumption in "high" and "low" economic growth scenarios.

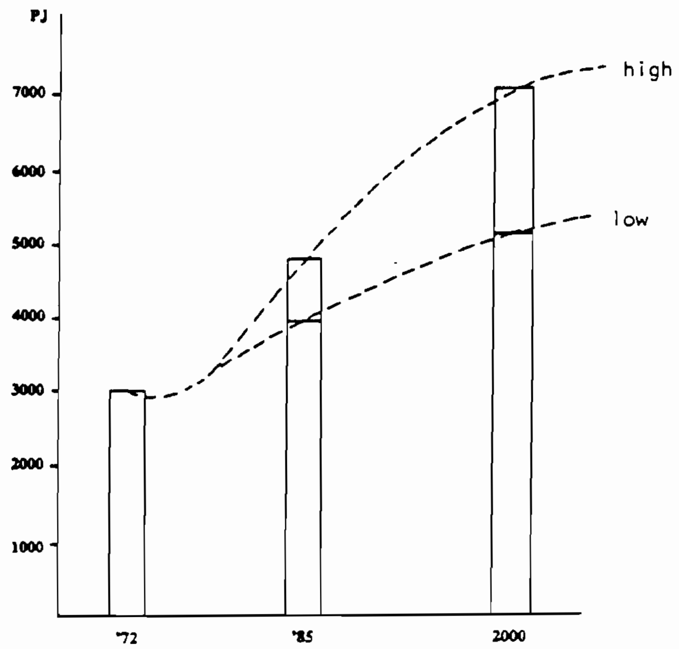


Figure 2. Energy consumption in the Netherlands.
Source: Energie Spectrum '79-4.

The government wants to reach this aim mainly by price mechanisms (although until now the price of NG is relatively cheap for big users!) and by regulations to promote the energy efficiency. For industry this aim must be attained by means of a so-called selective growth policy, which favours the set-up of energy-efficient industries.

This does not mean, however, that the Netherlands must dispose of the energy-intensive industries like oil refineries and (petro)chemical plants. The consumption of energy in the households will be reduced by means of prices, information, subsidies (on insulation), and innovations.

Besides the programme for energy savings, the government wants to reduce the vulnerability of the energy supply by means of the following intentions:

-- a restrictive management of Dutch NG supplies; for instance the contracts for NG-use for power plants will not be renewed,
-- risk management in case of a restricted supply of oil by means of stockpiling and dual-firing,

- a selective export policy for NG by means of revision of the export contracts which dated from the second half of the sixties,
- to obtain supplementary quantities of NG by means of importation (Norway, Algeria) and exploration of new locations where NG occurs.

About the "alternative" sources of energy (e.g., solar energy, wind energy, bio-mass, etc.), the government concludes that these sources will not contribute substantially to the energy supply before the year 2000. The increased use of coal as a substitute for oil (liquefaction) and gas (SNG) will be provided by importation and not by the renewed exploitation of the Dutch coal fields.

The Energy Situation

Although Holland is an energy exporting country, the situation today bears some aspects which may lead to serious energy shortages in the future. The following aspects are of importance here:

- the high population density,
- the energy-intensive character of the Dutch industry,
- the relatively low divergence in the energy mix.

The population density in the Netherlands leads to a relatively high energy consumption in the households, in transport and public services. This means that the government must guarantee a sufficiently safe and low polluting energy supply under all circumstances. Next to this, the energy-intensive character of the Dutch industry makes it necessary to develop a policy which ensures a sufficient and steady energy supply. This seems urgent because a number of the most energy and resources consuming industries are multinationals which may change their own policy as a result of changes in the global energy situation.

The relatively low divergence in the energy mix of today can be understood as a result of the large NG supplies and the specific energy aspects of the Dutch economy (types of industries and transport) that did not give any necessity for a divergent energy mix in the recent past.

Gas

Gas and oil have the biggest share in the total energy supply in the Netherlands. In relation to the aforementioned vulnerability, the government wants to restrict the consumption of NG from the Slochteren field for the following reasons:

a. the NG fields can be used in times of an acute crisis in the energy supply,

b. it has a function in the balance of payments,

c. it serves as a strategic reserve.

The government will try to maintain these functions of the Groningen gasfield until the year 2000 and longer, especially through means of acquiring supplementary quantities from new gas fields and the importation of (L)NG. Special attention will be devoted to these possibilities because of the attractive properties of NG, such as, low pollution, high comfort, and an already existing distribution system.

The government wants to maintain the share of NG in the Dutch energy consumption for over the next 25 years by means of an active purchase and selective marketing policy. The conclusion of new purchase contracts for (L)NG will be pursued, and a selective marketing policy will be achieved by means of price, restricted export, and a selective use in industry. The first priority in gas consumption will be given to the public provision.

LEG Siting in the Netherlands

In the next part of this paper we will devote ourselves to the siting aspects of two forms of Liquefied Energy Gases (LEG): LNG (liquefied natural gas) and LPG (liquefied petroleum gas). The main difference between the use of these gases is that LNG importation is mainly supplementary to the national gas supply, so the transport of LNG will go entirely to a big terminal in the Eemshaven area where it will be gasified and transported by the already existing pipelines to other destinations in Holland. For LPG, a totally different pattern exists and will probably be developed, as LPG will be transported and stored in a liquefied form in many different ways (railways, roads, and waterways) and in different immobile tanks and terminals. It is also a gas which is and will be used for many different purposes: in industry, in transportation (cars), and in households which are not connected with the NG gas distribution system. So the mode of consumption of the two LEG's is totally different.

The initiative for the importation of LNG came more or less from the authorities while the initiative to build a large LPG terminal in the Europoort harbour came from two oil municipalities. We will discuss these two different LEG's from a siting point-of-view and go somewhat deeper into the questions concerning the siting policy.

The Introduction and Siting of LNG in Holland

Holland has no experience at all with the transportation and landing of LNG and has little experience with the storage of it. The only installation where LNG is handled is a relatively small peak-shaving terminal on the Maasvlakte, near Rotterdam.

In 1972, the NV Nederlandse Gas Unie* suggested that it would be wise to import LNG from Algeria in order to save the Dutch supplies of NG. In 1975 the Minister of Economic Affairs had been asked to formulate a policy about this matter. The Minister first wanted advice from a Committee of high officials, especially on the aspect of safety. In 1977 this Committee concluded, after having executed a risk analyses, that it would be profitable to import LNG. Four sites seemed appropriate to land the gas. Two of these sites are not very appropriate from a safety and nautical point of view. The other sites seem appropriate but have some disadvantages in terms of a dense population in the vicinity and nautical difficulties. A few years ago the government took the decision to import LNG and later on marked the Eemshaven in the North of Holland as the most suitable port for landing. The whole decision process seemed somewhat peculiar because the amount of imported LNG is, in relation to the total production of NG, very small. (Holland produces $100.10^9 m^3$ a year, and half of it is exported.) The importation of LNG would not exceed a $6.10^9 m^3$ NG a year before 1985, however.

The reasons for the importation of LNG cannot be explained sufficiently on grounds of saving the Dutch NG supply. Next to this, the different composition of the Groningen NG and LNG makes it necessary to use LNG for specific purposes or to mix LNG with the Groningen NG. A few political parties have tried to change the governmental policy by introducing alternatives for the importation of LNG from Algeria. They did so by proposing an exchange contract with Italy or France, to which Holland is exporting NG. This would save a lot of energy in the liquefaction and the transportation of LNG and at the same time abolish the safety problems connected with the importation of LNG. Until now the government does not want to change its policy in this matter. Therefore it is meaningful to go into some detail in the different points of view of authorities and interest groups concerning LNG siting.

In 1974 the Minister of Social Affairs instructed the Organization of Applied Scientific Research in the Netherlands (TNO) to evaluate the hazards of the transportation, loading, and storage of LNG. The results of this study

*The Gas Unie is a firm in which the Dutch Government owns half of the shares.

were used for another which should give insight into the possibilities and desirability of an outside LNG terminal, situated on an artifical island, 16 km's off the coast. This island is only economically attractive when at least $40.10^6 m^3$ LNG (= 25 x $10^9 m^3$ NG) is imported. That is four times as much as was accepted in the TNO study. Because the TNO study has an inaccuracy of at least a factor of 10 in its risk calculations, problems arise when linear extrapolations of the risk figures are made. Secondly, a distance of 16 km's off the coast will not guarantee a safe situation on land when an accident with an outside terminal occurs. A study of the Rand Corporation (1976) demonstrates that there is much uncertainty about the distance from the storage on which large unconfined vapour clouds of NG may explode. So the use of the TNO data is debatable from a scientific point-of-view. Nevertheless, these data have formed the basis for quite a number of assessments of the risks connected with the importation of LNG of different authorities and interest groups. We will present here a short overview of the viewpoints of the different local and regional authorities and interest groups based on a study of H. Koekkoek (1980) (see Table 1).

The Introduction and Siting of LPG

LPG is, in contrast with LNG, already introduced in Holland into different sectors such as industry, the households, and transportation. During the last few years the consumption of LPG has increased largely due to it being relatively cheap.

For instance, the use of LPG as fuel for cars is increasing at a fast rate. Currently in Holland a quarter of a million cars are using LPG as a fuel source and this number is expected to increase to about 330,000 by 1985. Recently, the petro-chemical industry wanted to use LPG as a substitute for naphta and as fuel for their furnances. Therefore Shell and BP in Europoort have asked permission to site a terminal near the BP refinery in which they want to supply $1,5.10^6$ tons and at a later date 5.10^6 tons. The request evoked a political discussion which led to a risk assessment of the hazards attached to the transport, handling and storage of LPG and a comparison of different sites. Both analyses are executed by TNO. What is striking in this process is that no sophisticated economic analysis has been performed to obtain more insight into the benefits of the large-scale importation of LPG.

The involved industries in the Rijnmond area are claiming that they cannot compete with petro-chemical industries abroad if they are not allowed to land LPG on a large scale. This would certainly lead to a substantial

Table 1.

Type of Group	Information	Decision
STUNET: advisory Committee of the Government	Cost-benefit analysis on the location of an LNG terminal on an artificial island compared to a Maasvlakte siting	When more than 25 x 10^9 m^3 of NG is imported island location is suitable
Rijnmondraad: regional authority	Paper; 'LNG and Rijnmond,' which criticizes TNO-study	Refuses the location of an LNG-terminal on the Maasvlakte, landing and storage of LNG separated. Landing on an island, storage on the Maasvlakte
F.N.V.: union	Report: "Eemshaven energiehaven," based on TNO-study adapted to this location	Favours Eemshaven location for reasons of economic development and employment
N.V.V.: industrial union	Paper; 'Invoer van Vloeibaar Aardgas,' based on STUNET-data	Refuses the location of an LNG terminal on the Maasvlakte. Extended studies on hazards Gives attention to the alternative to import NG by pipelines
Working Party: (North Sea), cooperation of environmentalist groups	Paper; 'Over de invoer van aardgas' uses Californian norms on the allowable population density near by an LNG terminal	Terminal for LNG on the Maasvlakte and Eemshaven location is not acceptable from a safety viewpoint importation of NG by means of a pipeline from Italy and France
Government	TNO-studies, did not play a significant role in the decision process	Decides in March 1978 that LNG will be imported. Decides in August 1978 that LNG will be landed in Eemshaven

loss of employment in this area. At the same time they claim that the hazards associated with the landing and transportation of LPG are acceptable although some accidents with LPG have occurred. In Holland an LPG truck exploded when it was fueling a gas station. Fortunately the children of a nearby school had a day-off, otherwise a disaster comparable to that of Los Alfaques in Spain would have probably taken place. Later on a gas station burned down when the LPG caught fire.

A first reaction of the local and regional authorities in Rijnmond on the request was a paper drafted by a commission of officials. This commission gave positive advice about the landing of LPG in the Rijnmond/Europoort area. This paper was severely criticized by the inspectorate of public health in the province, which said that the dangers of LPG landing in Europoort were underestimated. The inspectorate wanted an analysis in which the hazards of LPG handling were calculated in connection with other hazardous activities within the area.

After a few hearings some political parties started to doubt about the acceptability of the LPG landing in Europoort. Two of these parties have motivated people to appeal against an LPG terminal. After a while 2000 petitions were handed over to the authorities. At the same time the unions and employers were expressing their views. The unions were in favour of siting an LPG terminal on an industrial island. The employers wanted a terminal in Europoort. The government preferred the Maasvlakte/Europoort location and after 1990 the island location.

Other ports (Eemshaven, Amsterdam, Terneuzen) are also in favour of their own location.

In March 1980 an agreement was achieved between the involved industries and the local and regional authorities about the siting of an LPG terminal in Europoort.

Table 2 gives a short overview of the different groups involved, with their information and decision or advice.

The Siting of LNG and LPG in Relation to the Energy Policy

It is difficult to see an explicit relation between the siting policy of LNG and LPG and the energy policy of the Dutch government. This is partly caused by differences in transport and consumption of the gases and partly a consequence of the booming oil market prices during the last few years.

The LNG siting policy of the government seems to be aimed at the creation of new opportunities to import LNG and not just at a substantial

Table 2.

Type of Group	Information	Decision
Industries, especially Shell and BP	Wants LPG as a substitute for naptha and fuel	Wants to site an LPG terminal in Europoort
Rijnmondraad) Rotterdam) Province)	Paper: "LPG-nota" written in cooperation with Rotterdam and provincial officials	Agree with industries. Refuse a terminal on the Maasvlakte
Inspectorate of public health in the Province	Hazards of LPG handling and transport must be analysed in connection with other hazardous activities in the area. Criticizes TNO arithmetics	Favours outside artificial island for LPG terminal
F.N.V. union	Consultates the North Sea Island Group for the possibilities of siting on an artificial island	Favours outside artificial island for LPG terminal in combination with other hazardous activities
Employers	Support the Shell/BP plans, agrees with the TNO-study	Opposes an artificial island, hazards are acceptable on land locations
Committee of Sea Ports	--	Landing of LPG on different locations
Government	Paper: "Grootschalige aanlanding van LPG"	Favours the Shell/BP plans, wants to consider the island location for the period after 1990

saving of the Dutch NG supplies. In times of serious shortages the government may conclude contracts with suppliers all over the world who are able to liquefy NG. This is not possible when NG is transported to Holland by pipeline. From this point of view one can even explain why the safety aspect did not play a significant role in the decision of the government to site the LNG terminal in the Eemshaven area. This site was chosen mainly for socio-economic reasons, because the industrial activities have been deteriorating there during the last years. It was expected that the handling of LNG would boost industrial activities in that area.

The decision concerning LPG was totally different for the government because the large scale introduction of LPG does not play an important role in the energy-policy of the government except in that it contributes to a higher divergence in the energy mix. The decision about LPG was of great importance to the local and regional authorities for maintaining economic activities and employment. Although risk analyses played an important role in the decision process, it became more easy for the Rijnmond area to agree with the Shell/BP plans because TNO had adjusted its arithmetic risk models in the meantime. This was done because new data was available about the detonation of LNG and even LPG. This data indicates that an unconfined vapour cloud of LNG cannot detonate (which would cause about 5000 deaths) and an LPG vapour cloud would just explode in a detonation-like manner. We may conclude from this that there is a weak relation between the energy and LEG siting policies in the Netherlands and that the safety aspect did not settle the matter, neither in the LNG nor in the LPG case. Our general conclusion is that until now it does not seem possible to carry out a balanced decision process for LEG siting.

REFERENCES

1. Ambtelijke Coördinatiecommissie, LPG-Nota.

2. Energienota deel II, Tweede Kamer der Staten Generaal, Zitting 1974-1975.

3. Goorden, W., and B.B. Scholtens. LNG, van Noodzaak tot Aanlanding. De Ingenieur 6 februari 1980.

4. Koekkoek, H. Essay on the risk evaluation of LNG in the Netherlands and the viewpoint of authorities, unions, and working parties, will be published in September 1980.

5. Leutscher, A., P.G. Schipper, and J.J. Schwarz. Risico-Analyse, TNO-Project 1, 1975, 1-10.

6. LNG, Verslag van de LNG-studiereis naar de V.S. en Japan. 29 januari - 15 februari 1978.

7. Nota Energiebeleid, Deel I, Tweede Kamer der Staten Generaal, Zitting 1979-1980.

8. Murray, F.W., D.L. Jaquette, and W.S. King. Hazards associated with the importation of Liquefied Natural Gas, Rand Corporation, R. 1845 RC. Santa Monica, 1976.

DISCUSSION COMMENTS

SINCLAIR: Mr. Cruchon will develop the international aspects of the LEG problem which have been mentioned at various points.

CRUCHON: Though my discussion will mainly concern LNG, it could perhaps also apply to LPG. Some facts indicated by Mr. Schwarz may be interpreted in an international perspective both with producing countries and other European countries. For instance, the choice between liquefaction and pipeline for gas transportation belongs both to the exporting and importing country.

The second thing that I would like to say concerning international implications relates to the timing of LNG siting terminal decisions. It is not only national decisions which are taking place, instead there is an interweaving of decisions in the importing and the exporting countries. This interweaving exists, for instance, with respect to contracts. Generally, when a contract is signed with an importing country, this contract specifies a time schedule for the fulfillment of the contract. And there is a link in the contract between the construction of the receiving plant in the importing country and the construction of the liquefying plant in the exporting country. From an importing country's point of view, the contract is not only a private business matter, but it is also a matter of international credibility of the consumer country.

RAVETZ: Did I understand you to say that even the pipeline from Algeria to France has technical problems because it is at a depth of 3000 meters?

CRUCHON: Nobody can say that we will be able or unable to set a pipeline between France and Algeria, and to operate it and repair it if there is a problem. The problem is not the same with Italy, where the sea water depth is less important.

RAVETZ: And would the cost of a pipeline be comparable to a liquefaction terminal?

CRUCHON: It is difficult to answer as long as the technical problems are still being studied.

RAVETZ: On the technical side, what are the reasons why Algeria now wishes to have a pipeline and not liquefaction plants?

CRUCHON: I do not think that it is my part to answer such a question.

CLARENBURG: As I understand it, there are two reasons for the change by Algeria. First of all the high technology involved. Secondly, the enormous capital investments which they cannot make by themselves.

SINCLAIR: What this suggests to me is that if one is really looking at national siting policies, one should be looking not only at import sites but also at the possibility of export sites and the risk associated with them.

DALL: To what extent has the present Algerian curtailment caused a change in the willingness of importing countries in Europe to consider potential future contracts with Algeria? I know that Robert Norton from Distrigas is an exception to the problem, because I understand Distrigas is continuing to receive Algerian gas.

NORTON: We did not receive any from May 25th until presumably next month. This was due, as it was in 1973, to technical reasons.

CAMPBELL: Did I understand you to say that there are fewer problems associated with export terminals than with import terminals?

CRUCHON: No, what I wanted to say is that the technical and environmental problems associated with export and import terminals might be quite different.

CAMPBELL: The fact that most of your exports come from countries which are underdeveloped leads you to have a different view of export terminals than import terminals. Is that really what you are saying?

CRUCHON: No. The basic fact is that the technical problems involved by an export terminal (which includes liquefaction units) are different from those involved by an import terminal.

THOMPSON: I am just trying to digest what the significance of all this is for the work that we are doing here. It seems to boil down to "when is a decision not a decision?" The answer is "when there is no choice." And when we have these types of constraints, international constraints, we find ourselves rather in this situation. It is like the difference between being very rich and being very poor--when you are poor, beggers cannot be choosers. We have been identifying decision points and talking about the decision maker and suddenly we discover he is absolutely threadbare when there is a decision to be made. There may be somebody sitting there who is pretending to be a decision maker, while in fact everything is decided in Algeria or somewhere else. We may be treating things as decisions that are not decisions at all.

SHAREFKIN: I get a different interpretation of what has been presented. How I interpret what has been said is that if you think in conventional terms of the benefit side of these decisions, you may be making a big mistake. In fact, there is a game being played with a few people on each side. The direct advantages of a particular decision can be very large and yet not captured by a conventional ordering. The question that Jaap Schwarz raised about the deficit does not seem justified on so-called economic grounds if you look at the fraction of imports that you get. It may, in fact, be a very large gain to someone, or some groups of people, if looked at in another way.

J. SCHWARZ: I think indeed that the benefits from the importation are not very important, but the benefits from a distribution terminal are very important. On the other hand the distribution of economical benefits, is not very clearly understood and are quite uncertain.

CLARENBURG: I have an addition to Mr. Schwarz's presentation. The Rijnmond authority was not afraid of LPG but it was seemingly so of LNG due to a report written by TNO known in our country as the Yellow Book (because it has a yellow cover). The debate on the Yellow Book, which contained methods on how to calculate risks, and losses has ensued since its first edition. In the case of a LNG terminal in the Rijnmond area the Yellow Book claimed there could be 16,000 deaths--a risk that nobody was prepared to take, despite the economic advantages of LNG. In the case of LPG, the risk of an explosion was higher than LNG, but the maximum number of deaths calculated was in the order of 500 to 800. Furthermore, LPG has very high economic value. Hence, it was viewed as acceptable.

J. SCHWARZ: Mr. Sharefkin raised a question concerning the comparison between the international power aspects and the siting aspects of LNG. From my point of view, it is difficult to understand what international power relations have to do with specific siting problems. These power struggles, on the other hand, could contribute to the decision to import or not to import LNG in Holland. The decision to locate in Eemshaven was very much influenced by social-economic factors. Perhaps it is not really a rational decision, perhaps a terminal would not boost industrial activities at all. But as a policy it worked because everybody said "its a good decision," especially the regional authorities.

M. SCHWARZ: It may be interesting to point out that the government advisory committee had been doing a lot of work talking to people getting their advice, writing reports, visiting TNO, undertaking risk studies, and other sorts of analyses. They clearly agreed that Rotterdam was the best site. The Gasunie, the Dutch Company, was also very strongly in favor of building the terminal in the Rotterdam area. Why the site was switched to Eemshaven is still a puzzle to me.

CLARENBURG: The Groningen area has serious problems--the problem of unemployment. There was a possibility that by introducing an LNG terminal the right chemical industries would also be attracted.

MEHTA: We have followed this Groningen siting criteria with great interest. It was quite obvious to us that the need to attract industry in the Groningen area played a very important part. It also seems that there were other reasons why Eemshaven was thought to be desirable by the Harbor authorities. One of these is that other industries had so far not settled in this area so that in future it will be possible to introduce safety measures which will protect people residing in the other areas that might be affected. Another reason is the waterways from the North Sea to the port are used by a very limited number of vessels, thus reducing the risk of collisions. Thirdly, the basin where the LNG vessels would be handled would be used exclusively by these gas tankers. The nearest two villages have populations of 5000 and 1000 respectively, so in case of a calamity the number of victims will, according to the Authority, be very limited.

MACGILL: I am thinking of international comparisons in the background of the people who opposed these plants on safety grounds, and I would like to know what the experience in Holland is.

REIJNDERS: In the case of Eemshaven the only opposition groups fighting were the environmentalist groups--both locally and nationally. Room for rational decision making was quite small because the government did not want to seriously consider the alternative of pipeline transport. Environmental groups also had reason for second thoughts, because Eemshaven has always been pointed to as a site for a nuclear installation. So they thought if we have an LNG plant, maybe we will not have a nuclear plant. Picking up one point about the Yellow Book, I was also aghast about it because many uncertainties were swept under the rug. There are scientifically sound reasons for views concerning the behavior of the vapor clouds that diverge from the governmental point of view, but if you go to court scientific debate is practically of no substance.

PRESENTATION BY MICHAEL THOMPSON

SINCLAIR: Michael Thompson would like to give a presentation that is essentially a social anthropologist's comment on the whole process of talking about siting.

THOMPSON: It occurred to me that yesterday, when we reached the point of comparing what went on in France with what went on in the United States, perhaps we had really reached the point where we needed a social anthropologist. As a social anthropologist I am interested in culture. I do not want to try to explain variations between countries in terms of the cultural differences (in the sense of national culture) between them. My interest is not in those gross cultural differences *between* societies, but more in those that are to be found *within* them--within American society, within British society, within French society.

As well as cultural convergence there is cultural divergence. The former can be captured by the concept of *national culture;* the latter by the concept of *cultural bias*.[*] One Frenchman may bias his national culture in one direction, another in a different direction, and so on. But the directions in which these biases are possible remain the same in any culture and this means that, for comparative purposes, we must focus on differences in the strengths of representation of these possible biases as we go from one country to another. For instance, what proportion of the French population is biased in the sort of sectist direction that seems to be causing so much "trouble" in California? And, when we know something of the different strengths of the sectist bias in France and in California we can go on to relate these to the responsiveness or irresponsiveness of government. So the cultural bias approach is essentially a comparative method for taking account of differences between nations in terms of their differing patterns of cultural divergence.

I think we have reached the point where, though we are all interested in LEG and are looking all the time at LEG, we have crossed paths with some other specialists who perhaps are not interested in LEG but rather are interested in a comparative study of institutions, and I think we should just explore this crossroads for a little while. Take the idea that public funds should be made available for those intervenors who do not have the sort of resources that are available to private industries and to public utilities. Dorothy Nelkin from Cornell University (who is one of the leading experts on the comparative study of institutions, and has worked in the United States, Germany and France) has proposed this is a way of redressing equity at public inquiries. But this assumes that all the parties are agreed on what is fair, and cultural analysis suggests that this is not the case. Let me try to illustrate what I mean with a little anecdote that sheds some light on the accusations of elitism that have been leveled at some of the intervenors—the ones that exhibit the sectist cultural bias. While searching around in the hope of getting some of the more "troublesome" intervenors to come to this meeting,* I was talking to Mike Flood, who is the energy spokesman for the British Friends of the Earth. He admitted, yes, it was impossible for them to be represented at the Mossmorran public inquiry because they had to spend all their money (40,000 pounds) on the Windscale Inquiry which took place almost at the same time. So I asked him about the idea of public funds being made available. Did he think it a good idea? Would it be a help? He said, "Oh, yes, but there are problems. You could not give it to just *anyone*." I could not ask what the criteria would be for deciding who should be given the money but there does seem to be something interesting about this moral prerogative of just one group.

*They tend to be wary of IIASA which they see as strongly biased towards technology (the casteist cultural bias). IIASA, for its part, shies away from the sectists for fear of losing its respectability in the eyes of its (casteist) clients.

Now that all the details are beginning to fall into place it is becoming clear that things tend to get done differently in different countries. There seem to be different institutionalized styles of risk management, in different countries, different ways of arriving at siting decisions in different countries, and different styles of government in different countries. The dominant style of risk management in the United States, you could, perhaps, characterize as the *regulatory* style of risk management. In France and in Britain (and it goes a little against the grain for me to put France and Britain in the same category), it is more of a *consultative* style of risk management. If we move to nuclear power for a minute, the Nuclear Regulatory Commission in the United States, looks to see what might go wrong, looks to see what should be done, in engineering terms, to prevent that from going wrong, and then tries to write a regulation, in legal language, which will prevent it from going wrong. In the comparable British Nuclear Installations Inspectorate the inspectors go around the plants and look at what might go wrong. They then talk, in engineering language, with the Resident Engineers (and others) and work out what needs to be done to prevent it from going wrong. There is no drafting of regulations. So in Britain the process is pretty inaccessible to anybody who does not speak the engineering language. In the United States the process is accessible to anybody (or, at least, to anybody with the requisite time, resources and education), and nearly every regulation gets challenged in the courts. So there is a very marked difference between the regulatory style and the consultative style of nuclear risk management.

And there are marked differences also in the way siting decisions are arrived at. In the United States it is a very public process with a lot of public hearings--it is an enormously open procedure. In France it is done very much inside the administrative framework. We have heard something as to how this is done--how very much it is away from the public eye. It is interesting, therefore, that in the system in America, which is the most open, that has ever been known, Norbert Dall is complaining that when the decision is finally taken, it is "off the record." Despite the fact that every door had been opened, there is always one door, somewhere, that is closed and the decision is made behind that door. So there would appear to be a profound difference, not just between openness and secrecy but between trust and distrust as well, as you go from California to France.

Let me touch very briefly on the different styles of government. France is very centralized, almost on a simple single level style of government. There is nothing like the problems of decentralization and multi-level that we have between California and Washington. So there are very pronounced differences in the styles of risk management, in the ways of arriving at siting decisions and in the styles of government and cultural analysis which give us some sort of frame for handling them.

Now we can get down to business. When we look at what goes on in one country, and what goes on in another country, and we see some little thing that looks rather nice, we think to ourselves, "could we just take this procedure from Britain and take it to the United States?" or "could we take that feature from the United States and just fit it into France?" We are looking for prescriptions--possible ways of making things better--and transplantation is very tempting. The really big question, I suppose is, "is transplantation possible?" And, as far as I see, the answer is "sometimes it is possible, and sometimes it is not possible." The problem then becomes "when is it possible, and why?" Because, if we knew when something could be transplanted and when it could not then we could be doing something to improve the processes.

It seems to me that institutions of all kinds become effective or become paralyzed according to whether they enjoy or do not enjoy the credibility of the populace (or, at least, of the politically effective populace). So transplantation will be effective if the institution or procedure, or whatever it is that you have picked up from one country and want to put down in another country, does still continue to enjoy credibility in the social and cultural soil into which you put it. If we pick out something from Britain or France and take it and plant it into the cultural/social soil of the United States, or conversely from the United States to various European countries, will it take root?

Take for instance, this idea of the consultative style of risk handling. Could you, if you thought it was a good idea, transplant that to the United States? What would be required for that: what conditions would have to be satisfied for that procedure—that institution--to flourish once it had been transplanted? Well, I have noted down a few conditions that I think would have to be satisfied for it to enjoy credibility. There would have to be trust in experts, and I think the American system is very much characterized by the distrust of experts. It is almost as if by being an expert you are disqualified from having a say in anything. There is in Western Europe, and I think in the Soviet Union as well, a very general assumption that the experts are the people to handle these things. That you can trust the experts and that you must trust the experts, otherwise where would we be?

Another thing is that there would have to be a considerable acceptance of secrecy. The consultative style of risk management is not particularly open, but is conducted between experts and in technical engineering language and it requires that a lot of talking goes on behind the scenes and a lot of candid interchange, and if that was all on the record it would not happen. Then, it would be difficult to make the consultative style work when there was not much centralized governmental control. Another point that occurs to me is that for the consultative style to operate you have to have the qualitative expert use of quantitative analysis. I think this was made very clear from the French explanation of how things were done. Yes, you have quantitative analysis and you then take it with a very large qualitative pinch of salt and just use it as some sort of rough guide to indicate where the weak links in the chain are. I think something rather similar happened with the way the quantitative risk assessment was used in the siting decision in Holland.

The question then would be: "if those are the conditions that have to be satisfied for the transplantation to occur, would they be satisfied in the United States?" I think probably not. Because all those conditions (and we could add more) add up to a relationship between government and governed that can be, and has been, characterized as *deferential*. In such a regime you have a populace, that, by and large, is prepared to be governed; to go along with what the experts say; to accept quite a lot of secrecy because they feel that whatever is going on there in secret is acceptable, and is in their interest. But the United States system, by contrast, can be characterized as operating in an atmosphere of *truculence* --the adversary system. (The fact that there are more lawyers per square inch in the United States than in any other developed country.)

There are two studies on risk (neither to do with LEG) which illustrate this point. One is the study of what happened a few years ago with the Swine Flu epidemic. A new kind of flu spreading across the world was identified as the Spanish flu that killed so many people back in 1918-19. The reaction in the United States was very open--there was a great deal of public concern and the President of the United States went on television and said that every man, woman, and child would get inoculated against it. In Britain, somehow or other, it did not become so public, and the public health authorities said, "lets wait to be sure it is the virus we think it is." In Canada, it was somewhere in between these two reactions. Fortunately for Britain, it turned out not to be the Spanish flu--the dangerous one.

When it comes to smoking and health, I think the different ways in which the hazards of smoking have been handled in the United States and in Britain can only be understood in terms of these cultural and social differences--deference in Britain, and truculence in the Unted States. The report on smoking and health in Britain was published by the Royal College of Physicians which is an august, self-governing medical body, fiercely independent of government. In the United States it was produced by the Surgeon General--an arm of government. When, after they have deliberated for a long time, the doctors--the Royal College of Physicians--pronounce that smoking is dangerous, people in Britain, by and large, believe them. That does not mean to say they stop smoking, but at least they do trust and believe in experts. In the United States, apparently, when doctors tell people that smoking is harmful to their health, the general reaction is that the doctors have discovered yet another way of screwing more money out of them. That, really, is a very rough generalization of the difference between truculence and deference. That is all I wanted to raise.

Having reached the point where we understand that things get handled differently in different countries, we need to turn to cultural analysis to tell us why. By providing us with a typology of regimes--of relationships between government and governed--cultural analysis gives us some prescriptive guidelines. Transplants between like regimes are likely to be successful; transplants between unlike regimes are likely to be unsuccessful.

DISCUSSION COMMENTS

VINCENT: I would like to clarify some statements made yesterday which were not very complete. The legal process, with respect to various projects in France, includes a public inquiry, though not in the same style as in the US, the Netherlands, and the UK. All citizens are able to have an idea of what the project is about by consulting all the documents which are displayed in different places. After the decision has been taken anyone is entitled to bring legal action against the decision through the courts. This does not happen very often, but has happened in the last few years over some nuclear energy projects. In some cases, the decision has been delayed a long time due to these legal actions.

The second point concerns the statements, files, and reports presented as evidence at the public inquiry. We try to write these reports in a way so that everyone can understand. Sometimes, however, this is not the case, since it is very hard to explain clearly technical data or information. But the administration tries to clarify the project by providing a summary.

The third point concerns the level of government at which the decision is made. It is true that all decisions are taken on a national level. Yet, most projects are first handled at the regional level, and then taken up by commissions or committees where the values, traditions, and local interests are represented.

SALZ: I would like to underline some of what Mr. Vincent said. I do not think it is the time to discuss transplantation of decision structures, but I think we have to work in the field of diagnosis, of how these decisions are actually made. I have the feeling that if we separate the American structure from the rest of the world, everything is the same. But this is not the case. There are profound differences among Holland, the Federal Republic of Germany, and France. I feel a somewhat unfair tendency to separate the American system from the others.

CLARENBURG: I cannot buy the assumption, as Mr. Thompson said, that the US system is the most open. I challenge him that 4500 pages of public hearings means an open system. In my country, when this happens, and it does happen, the special consulting bureaus try to make an analytical commentation of 25 pages, which can be read by everyone. I think this system is much more open than a closed book of 4500 pages.

THOMPSON: In the United States the concern for openness enables those with the requisite skills (historians, for instance) to study all kinds of things that they simply could not gain access to in Britain and some other countries in Europe. That is what I was trying to convey.

V. CONCLUDING REMARKS

AHERN: I have been very pleased that I have been able to make very rash generalizations and not be personally attacked. So I will make two more. One, because we are dealing with liquefied gases, I sense a sort of late 20th century technology, the different countries, the issues, the people involved, the kinds of things we are talking about, even the analysis, does seem to have much in common. Our differences are much greater on what we eat for breakfast or how we educate our children than on how we deal with liquefied gases, refineries, etc. I thus see a lot of commonalities.

Secondly, the different sub-cultures in the individual countries seem to have some similarities as well. With some work and language learning, I feel I could walk into Mr. Clarenburg's job and he could walk into my job and Mr. Campbell could also walk into my job. We echo the same things—the worry that our agency's point of view will be presented in here, "sensitivity to turf."

BARRELL: I would certainly count it as a very successful conference, and I would like to join the other people in saying this. I would like to add a word of caution about Mossmorran. In this particular case, you have only heard part of the story. Niall Campbell and I have been inhibited by further public inquiry proceedings from saying a lot more. I do not think that, as presented, it has been a good example of how we control the siting of major installations in the UK.

CAMPBELL: I came expecting to find out how things were done elsewhere and I think that has come true.

CIERAAD: I think this has been a very informative meeting, where the pitfalls of analysis and the usefulness of it as well, have been explored. I think that we must conclude that the use of analysis in politics must be very carefully looked at. This process should be carried out by politicians, lawyers, and especially technicians.

CLARENBURG: It might sound a little bit harsh, but I think I have wasted my time. I also feel that the outcome of this conference would have been different if it were done in France, the Netherlands, or Germany.

In the concluding remarks very little or no attention has been paid to vital problems for decision makers as equity, unacceptable risk, limits to risk analysis, political decision process, etc. These problems are also of urgent importance because decisions are taken everyday. We apparently have not bridged the gap between scientists and decision makers. I strongly recommend that this mutiny be continued and focus on the decision making process.

CRUCHON: I quite agree with Mr. Clarenburg, I found in this meeting the diverse information, and the presentation of experiences, to be interesting but I am not sure if the treatment was what I expected. I still do not see how they all fit together.

DALL: If the Greek philosopher Plato were looking in on this, he would probably say that we had a lively debate in a very elegant cave and that there is no certain knowledge here, only opinion. Hopefully it is a formidable opinion that can stand the scrutiny and structure of due process. In the real world, Plato notwithstanding, there are decisions that invariably are contingent decisions. I think they must be legitimate and informed decisions if our decision-making institutions are to endure in these difficult, sceptical times. In this process, hazard analysis, risk analysis should play an educational role. Our experience, biases if you will, needs to be broadened. For one, I think that has happened here during the past four days. Other practitioners in the field need to hear about the issues we have discussed here. Hopefully, they, in turn, will contribute to our dialogue. There may be little progress, but we may learn from each other's past mistakes. I appreciate the opportunity to be here.

DEUTSCH: Practical people have told us there are limits to—and disbelievers in--risk analysis as a decisional tool. Now we know we have to crank in some intangibles and some social factors in these analyses to add credibility to them. I would rather that IIASA spends time on that instead of going overboard in finding out why a project has failed in California and succeeded elsewhere.

KEENEY: Like everybody I came with a framework, national as well as discipline-wise. The meeting has broadened my thinking through the discussions and the reading of papers.

LINNEROOTH: I have been reflecting within the last few minutes about what have I learned from this conference. In referring back to questions posed during the first day, the important message is that these questions are not as simple as they look. But they are very important questions. There is probably no more appropriate place to address the different roles of analyses in different countries, than at an International Institute of *Applied* Systems Analysis.

MACGILL: With future developments now being considered in the United Kingdom we ought to see to what extent these will constitute improvements on the case history of Mossmorran.

MEHTA: I had hoped that things would be not so black and white as they seem to be. I would like to suggest that we at least acknowledge certain simple/naive facts—the substances we are dealing with are highly dangerous and the technology is far from perfect. Wherever possible we ought to spend more time dealing with siting. At a lot of conferences we usually go away and do the same thing as before. In this instance I hope that we have learned something about what is better. As of yet, democracy is a bit of a mockery particularly in the initial approval, the right of appeal and following the decision.

NORTON: This looks like a very mixed bag that you are going to try to pull together. Looking at it from an industry point of view, I see it as what we should be doing in an area where hazardous materials are used. We should be drawing up the legislation any way we can, we should be working in the formulation of regulation that will result from legislation and working with those people who will be involved in implementation. This is going to involve political hassles and involve analysis, and contention as to what industry should do. It must become sensitized to the various needs, biases and perceptions of those other people who are involved in the process and then in a fairly positive manner recognize this, go about the business of running a terminal.

OTWAY: I thought this workshop was excellent. I was also planning, as Jerry Ravetz was earlier in the week, on not staying, but found that this was the first workshop I have attended in quite some time where I frankly thought I was not wasting my time. I enjoyed two workshops here--one was about LEG and the other involved talking about the most important issues of modern society. Implicit in the discussion is the future of IIASA and the future of analysts and analysis. It all worked very well and a very interesting process got started. This is the first time I have seen all the issues posed in one week, even though we did not synthesize them. I think it would be a shame to let it drop. It would be a wonderful idea if IIASA could do this one more time to keep this process going.

OSEREDKO: Dr. Maksimov and myself would like to bring to your attention a topic which we believe can be studied at IIASA, specifically in connection with international collaborative considerations which may arise due to construction of LEG terminals. It is desirable to work out international models/modes and the interpretation re the design of LEG terminals and the application of risk analysis in order to provide maximum safety.

RAVETZ: It is pretty clear that the conference did not pull together its theme–though it made tidy sentences in which all cosmologies were represented. However, given that, I think that this was one of the more pleasant conferences I have attended and also one of the more successful in educating everybody–not only on the details of LNG, but on the whole problem of regulation. One reason for this very unusual success is this very fine mix of people, including representatives from the university/academics community, government, industry people, regulatory agencies and intervenors, all of whom have different styles from each other. I feel that no one has been able to dominate and no one has been able to really feel left out by the majority. I think also the Chairmanship deserves some praise.

One reason for the undercurrent of excitement is that I believe there is going on quite a rapid change of ideas about analysis among people here at IIASA and we may have just been going through an extremely important week in the history of IIASA where people see the real world intruding and yet are not frightened by it. Although people have been trained as analysts, nonetheless, they have remained quite acute, political, social animals.

Finally, for recommendations. One is for some sort of comparative studies, but I feel there is a lot to be learned in this type of process, and that depends on the risk end. A very useful starting point is the way risk analysis is used as a tool of design. You already have three competing philosophies—deterministic, probabilistic and mathematical.

REIJNDERS: I found this conference to be different from what I originally anticipated and do think that the proceedings of this meeting should definitely be published.

SALZ: To me the result of this meeting is rather heterogenous. It is a little bit too early to put any value on that. Nevertheless I think one thing has been achieved--an international exchange of ideas and the development of new contacts. On the other hand, there is still a lot of work that needs to be done, and is being done by IIASA. As a member of the Federal Ministry for Research and Technology, this project done by IIASA is part of a future research program organized by our ministry which has the title Risk Research and aims at investigating technical risk by combining engineering with contributions on the social and political aspects of risk management.

J. SCHWARZ: I have learned in these few days that the decision process will not really satisfy the solutions in the end--the problems of high technology. I do have this message for IIASA: "go on making analysis!" Because I am firmly convinced that this can provide societal pressure to search for other solutions. This is a good time for it as a lot of countries are starting programs on innovation and most aspects of these innovations have to do with governmental policies regarding safety and environmental aspects.

KLAUS SCHWEIR (FRG): I think that everything that has to be said has been said. It was quite remarkable that such different opinions could be brought up at this table, in a quiet and relaxed manner.

SHAREFKIN: I have learned a lot here. There might be more future discussion on the legitimacy of institutions: the governance of corporate persons and the design of institutions to measure facilities. I do not think it is necessary any more to rely solely on comparative analysis, or thinking about how different institutions might work. There is a new field that talks a lot about the relationship between institutional structure and decisions, especially with regard to legislative bodies. I feel that this is a richer avenue to explore than comparative analysis. I do not think the existing national examples are rich enough to provide us with something substantial.

VINCENT: The most important thing I have received from this meeting is a recognition of the strength and interference of the media in the different countries, best illustrated by the Mossmorran case.

SINCLAIR: I think we have received the following message from this meeting:

(1) that we should look even more deeply at the institutional aspects of the use of risk analysis, and by institutional I mean formal and informal and that includes politics.

(2) We should have a look at the timing and level of precision of useful analysis. .

(3) We would like to devise a schedule for gathering information and disseminating it to improve procedures. Can we design some way of collecting this information and disseminating it? Do we do it all at once? How do we keep the dynamic process of adding information as part of the political process?; and

(4) I think we have to look at this question of acceptable risk even though I am not quite sure how we do this.

APPENDICES

APPENDIX A

IIASA LNG SITING STUDY

This note summarizes the aims of a current research program at IIASA which concerns itself *inter alia* with the bases of decisions on siting of LNG terminals.

BACKGROUND

The siting of any large scale energy, chemical handling or production facility poses decision problems which involve economic, environmental and safety considerations as well as technological choice. A research project at IIASA is concerned with the systematic analysis of these decision-making processes with a view to improving their efficiency if appropriate. As an international research organization of wholly neutral stance and established analytical expertise, IIASA is perhaps uniquely placed to find socially acceptable solutions to problems involving technological risk.

Since liquefied natural gas (LNG) is already an important fuel for energy importing countries and many new developments involving these and other countries are at various stages of planning, decisions on LNG terminal siting form an obvious example for study. Such an LNG study is also apposite for other reasons. For example, it may be argued that because of its relative novelty - the first commercial LNG cargo was shipped in 1959, the first regular service between dedicated terminals in 1964 - it has received more scrutiny, in some respects, than many other more familiar cargoes. Thus, comparison of LNG siting procedures with other apparently similar problems could also be fruitful.

INTRODUCTION

Considerable experience has now been accumulated by the major LNG operators - 9 of the world's 18 import terminals with 52% of the world's receiving capacity are in Japan and 4 of the 11 export terminals with 41% of the world's liquefaction capacity are in Algeria. Terminals are sited in another 5 exporting and 5 importing countries and new plans for LNG terminals are underway both in these countries and in a further 12 countries. There is necessarily a wish for guidance on the part of those wholly new to LNG trading, a look to precedent as well as a requirement to develop national procedures to handle LNG siting decisions. The precedent safe operation is reassuring but not in itself guidance as to the possibility of serious accident.

The siting of an LNG facility involves conflicting objectives. As an example, consider the proposition: "Improved safety and environmental acceptability of a terminal can be attained by siting offshore." Almost invariably an offshore siting will be more expensive, sometimes many times more expensive than on onshore one. It is clear that there will always be some physical distance beyond which the whole project becomes economically infeasible. How, even in the absence of this constraint, should the distance offshore be determined? Would it suffice to ensure that third parties could not be subjected to fire or explosion hazards from the worst conceivable incident? It is, further, by no means axiomatic that environmental quality would be enhanced or be regarded as being enhanced by an offshore siting.

There are no wholly objective means to resolve the conflicting aspects of environmental quality, public safety, and cost optimization. Several analytic methods can, however, be used with effect on questions of site evaluation, e.g., cost-benefit analysis, risk-benefit analysis and risk assessment. Such methods are not always adequately incorporated into the political decision-making process. This can result, for example, in cases where technical and economic analyses find a site to be desirable only to have planning permission refused in the course of the subsequent political process. Technical and economic analyses should be extended to provide results that more effectively assist political decision-makers in implementing coherent policies.

OBJECTIVES

1. To describe existing LNG siting procedures in each of several countries.
2. To draw conclusions concerning the relative strengths and weaknesses of the various procedures.
3. To develop suggestions to improve siting procedures.
4. To determine whether LNG siting procedures are generalizable to other technologies.

MODUS OPERANDUM

Six LNG base-load import sites have been tentatively selected for initial study; one in each of six countries: France, Japan, the Federal Republic of Germany, the Netherlands, the United Kingdom, and the United States. Of these only three (France, Japan, the US) have existing LNG terminals. Later, at least one export terminal, possibly in the USSR, will be considered.

It is necessary to acquire the technical data base concerning the risks and impacts of each site. Then, to the maximum extent possible, analyses will be performed to develop uniform comparisons across all the sites considered in this study. Few, if any, decisions concerning the siting of any large scale technological plant are made by fiat, but rather from interactions of the many participants in the process. An important aspect of the research is therefore comparative analysis of decision-making in each of the countries under study.

The form of the decision process may itself produce biased decisions or time-consuming schedules, so research which utilizes IIASA's unique access to decision makers in different countries should also examine the flexibility and efficiency of the various institutional arrangements.

INFORMATION REQUIRED

In addition to the technical data mentioned above, analyses of the decision-making processes will require answers to the following questions:

1. Institutional Structures

   What institutions are involved in the decision-making process? (Those institutions will include the industries involved, government planning and regulatory agencies, local governments, environmental groups, citizens and special interest groups, etc.) What are the relationships among those institutions concerning authority, responsibility, and representation? How are the decisions concerning LNG siting related to higher-order decisions and policies concerning regional and national energy supply and coastal development? Who are the interested parties? What laws, regulations, and standards define and constrain the decisions? What is the role of the judicial system, or the administrative courts? How do the scientific and technical expert communities participate? What institutions define, fund, direct, and carry out the technical analyses?

2. Alternatives

   What siting alternatives are considered? How were those alternatives developed? How could new alternatives be developed?

3. Information

   What types of information on alternatives are available for each decision? Are any types of formal analysis, such as cost-benefit or risk-benefit, brought to bear on the problem? How is that information used? What are the formal and informal communication channels? What are the sources of information? Who decided if more information should be collected before a decision is made? How are disagreements in information resolved? How is uncertainty handled? How are LNG planning applications considered relative to those involving other more dangerous but more 'familiar' cargoes?

   Because of the characteristics of the safety risks associated with LNG storage, i.e., the small possibility of a large-scale accident, the manner in which these are taken into consideration is of special interest. Is a formal risk analysis prepared for each alternative? If so, in what terms are the risks expressed and how are they evaluated? Is there an attempt to quantify the risks and benefits in a formal sense or informally through rules of "reasonableness" or "best practical means for their mitigation?" Is there any attempt to include public perceptions of the risks?

4. Representation of the interested parties

   What are the relevant values and beliefs of each of the interested parties? How are these incorporated in the decision-making process? What is the general degree of public involvement? How open to public scrutiny is the decision-making process?

5. Decision-making

   Is there a systematic comparison of alternatives? On what criteria are the alternatives judged? Can comparisons be made between the safety and "acceptability" criteria for LNG and for other large-scale technologies? What are the stated and unstated objectives involved in making each decision? What are the broader institutional objectives of each party involved? How are conflicting objectives resolved? How do the following decision characteristics enter in:

   -- flexibility (ease of adapting to future developments)?

   -- permanence (stable policy and legal context to encourage the appropriate long-term investment, etc.)?

   -- defensibility?

   -- timeliness?

APPLICATION OF DECISION-THEORY

There are four ways the application of decision-theory techniques can reveal aspects of decision-making processes.

1. Fitting of the various decisions into the formal structures of decision-theory, so that implicit social value trade-offs and probabilities can be inferred. These inferences must be interpreted with great caution since they may reflect the structure of the decision process more than any actual value trade-offs.

2. Examining the consistency of the decision process. It may be in the best interests of all parties to have an explicit, single policy regarding LNG siting, yet a decentralized process may lead to inconsistent decisions. Retrospective analysis can reveal those, and may be able to shed light on the nature of a single desirable policy.

3. Testing the various institutional arrangements to determine if and how the form of the decision-making process itself may produce biased decisions or time consuming and inefficient schedules. This research may generate conclusions on the flexibility and efficiency of different institutional arrangements, which can then be checked using IIASA's unique access to decision-makers in different countries. Such studies would be enhanced by the use and development of new theoretical tools that have been developed recently at IIASA and elsewhere for group choice procedures, design of incentives, and decision-making where there are conflicting objectives.

4. Structuring and systematically representing decision-making processes in such a way that comparison can be made from country to country. Most descriptions of the processes have been in forms not so readily amenable to analytic comparison. By representing decision-making processes in terms of decision trees, information flow diagrams, and evaluation models, descriptions of the processes can be developed.

DECISIONS AND VALUES

There are several fundamental characteristics of decision-making processes that will vary from country to country. These include the structure of the processes, what institutions are involved, whose values and beliefs are incorporated and how they are incorporated, the general degree of public involvement, and the value trade-offs that are expressed or implied. There are also characteristics of the decisions themselves, including the decisions' timeliness, flexibility, stability over time, appropriateness of incentive effect, clarity, incorporation of all relevant information, self-consistency, and match between value trade-offs of the interested parties and those reflected in the final decision. A systematic comparison of these characteristics across countries can be developed into correlations between characteristics of the decision-making process and characteristics of the resulting decisions.

In addition to the above features of the decision-making process, <u>the results or outcomes of that process must be examined</u>. A set of questions involved in this examination include:

-- what occurred locally at the site?

-- what effects were there regionally?

-- what effects were there in similar sites elsewhere?

-- what effects were there on national policies,

  (a) for this technology?
  (b) for related technologies?

One problem here is to determine how many of the results are attributable to the "nature" of the decision. Was the final decision the single "cause" of the effects? How are transient effects introduced at particular stages of the construction program dealt with? Are they treated ad hoc or dealt with in some way which could be described as planning? Were such lessons, reactions, etc., learned and used in the next decision? What are the complications of different national styles, cultures, regulations?

CONCLUSIONS

It will readily be appreciated that it is of central importance to the successful outcome of the research outlined that IIASA obtain as full access as possible to required information from each of the interested parties in each terminal and country which is approached for study. We hope in return that we shall provide not only useful suggestions but also a neutral-ground meeting point for parties to exchange views in an objective and emotion free environment.

The study's conclusions will include suggestions for improved decision aids that present results of technical-economic analyses in ways most useful to the existing decision-making process. Such improvements might include increasing the number of dimensions evaluated to allow site appraisal to reflect more closely the reactions of each of the affected parties. In addition, such improvements might involve evaluation algorithms that do not have the formal, normative character of cost-benefit or risk-benefit calculations, yet are more descriptive of the results of the actual decision-making process.

Where appropriate, conclusions will include suggestions for improved decision-making procedures that are compatible with existing institutional structures. At a more ambitious level, conclusions will include suggestions for improved decision-making procedures that involve modifications to existing institutional structures.

REPORTING

IIASA working papers of research reports will be produced and where appropriate results also communicated in scientific literature. Case studies will be produced for a minimum of four countries (in particular, the Federal Republic of Germany, the Netherlands, the United Kingdom, and the United States). A Summer Study will be held in 1981 on "Decision Processes and Institutional Aspects of Risk" with a subsequent publication in 1982. A final report of the LNG siting study is geared for summer 1982. Two versions are scheduled for publication during that year on "Risk Analysis and Decision Processes," one in German and one in English.

APPENDIX B

THE IIASA TASK FORCE MEETING: LIQUEFIED ENERGY GASES FACILITY SITING ISSUES PAPER*

INTRODUCTION

This paper is intended to set the context and tone for the Task Force Meeting. It presents background information, as well as the questions and issues to be discussed in the course of the meeting. It is hoped that this paper will help direct the general discussion sessions.

The opening "Purposes" section lists the several objectives to be achieved at the meeting. The following "Background" section presents the LEG facility siting problem in very general terms, setting the stage for the presentation of issues that comprise the rest of the paper.

PURPOSES OF THE MEETING

The Task Force Meeting has several purposes, listed here in roughly the order in which they will be considered. The last three objectives are not specifically built into the agenda, but will be pursued in discussion sessions after the first two purposes have been adequately fulfilled. There may not be enough time to debate these last three objectives very thoroughly in the course of this Task Force Meeting, though they represent important final goals to be sought in completing the project. It is therefore hoped that some attention can be given them at this intermediate stage in the project.

The purposes, then are to:

1) represent siting processes:

   -- examine each country's siting process
   -- develop useful representations of those processes that can be generalized across countries

2) study the role of technical, economic, and risk analyses in those siting processes:

   -- determine whether the nature and size of the role is appropriate;
   -- identify ways that the role could be changed

3) develop measures of "quality" of siting processes and outcomes by answering the questions:

   -- what makes a siting process "good"?
   -- what makes a siting process outcome "good"?
   -- are there measures of "quality" of siting processes and outcomes that apply equally well in more than one country?

*This Issues Paper was written by Joanne Linnerooth.

4) develop recommendations for more effective technical, economic, or risk analyses

5) develop recommendations for appropriate, incremental, and feasible changes in siting processes to make more appropriate use of relevant analyses.

BACKGROUND

The siting of large LEG handling facilities poses difficult technical, economic, and political problems. Proposed and existing terminals are large-scale operations located in coastal zones and near major shipping channels, some in major harbors or near population centers. They require considerable amounts of land and capital, and represent a large concentration of energy at a single site. Since the technology, like any other cannot be proven absolutely safe, there exists a risk, however small, to the surrounding population. The location of a terminal, thus, can be a major factor in its safety. The magnitude and extent of any resulting damage from an LNG/LPG spill can depend on the proximity of the terminal and storage sites to other industrial and residential areas. Since a site remote from a populated, industrial area is usually costly in terms of both higher gas prices to the consumer and environmental degradation of the area, the choice of site poses the problem of tradingoff benefit versus risk.

This tradeoff, by no means unique to the siting of LEG facilities, has become a topic receiving a great deal of current attention. An area of research, usually known as risk assessment, has evolved to answer questions of "what is an acceptable risk?" or "how safe is safe enough?" A standard approach to such questions is to estimate the risks, in probability terms, and to determine the acceptability of these probabilities. In this way, the debate has often narrowed to inquiring whether, for example, a 10^{-6} risk of death resulting from the introduction of a technology, is acceptable or not acceptable.*

It has become increasingly clear that this approach to the problem is helpful, indeed necessary, but not sufficient, in determining the acceptability of a large-scale technology. Many of the concerns germane to the debate cannot be addressed by a risk analysis alone. Indeed, the attention given to the safety issue may, in some cases, be reflecting deeper, and more vague, concerns over the future of a high-technology society. These

*It has been suggested that, where appropriate, this question be framed in terms of (a) the background risk--is the population routinely exposed to this risk from natural sources?, (b) revealed preferences--does the population accept other hazards posing a 10^{-6} risk of death?, or (c) expressed preferences--if questioned, would those affected be willing to accept this risk given the benefits of the technology?

concerns might be articulated in many ways, including an expressed distrust of the "expert" calculations or an unwillingness to accept the imposition of any probability of an event judged to be catastrophic.

In addition, the issue may be one of who bears the risk and who receives the benefits. Nearly every choice affecting public safety will yield results desirable for some groups and undesirable for others. Ultimately, the query "how safe is safe enough?" is a political question, to be decided in the arena of political choice. No totally accepted technique exists for separating completely the fact and value judgments required.

It is this reasoning that has led the IIASA Risk Management group to choose an institutional approach to the analysis of problems dealing with technological risk. Since the question whether an LEG facility poses an acceptable risk to the public, or whether it should be sited at a more remote site at higher cost, is finally decided on political grounds, it is important to understand the participants, institutions and processes making up the decision-making forum.

The most acceptable risk is that associated with the most acceptable option, and this choice depends on the problem definition. So, as a start, it is necessary to identify exactly what it is that is being decided. Is the choice simply where to locate an LEG import or export facility bearing in mind the economic, environmental and safety factors? Or is the choice rather one of energy policy, a question of whether the proposed project is consistent with long-term energy goals taking into account conservation measures, development of alternative energy sources, public safety and economic growth? The breadth of the decision, to a large extent, defines the processes which will evolve to handle it and vice versa.

Turning to the decision process, there are several levels at which the IIASA group investigations advance. On a descriptive level, we ask who are the participants and interested parties, and how do their preferences weigh in the final choice of the site? Who makes this final choice: the national, regional or local authorities? How is this choice made? We shall want to investigate both the formal and informal channels by which the views and demands of these parties are communicated.

On a more analytical level, we will identify the crucial decision points and ask why these decisions were taken. What factors had the most weight in forcing the choice? What were the motivations of the parties, and what were their institutional constraints? Another important criterion for analyzing the institutional procedures is the types of information being fed into the process and the channels open to the information flow. Who collects what information, when? Who has access to this information? How is it biased by the institutions or groups who manage it? A related question is that of how the choice of a sovereign agency, with its mix of professionals, can influence the decision.

On yet another level, we shall try to evaluate this process. How legitimate are the procedures as viewed by the parties involved? If there is a forum for public debate, how effective can this forum be in light of the complexity of the issues? Can the problem be openly discussed in all its aspects? Most importantly, we must ask how the public perceives the procedures in terms of their openness and fairness.

Of special interest to the IIASA work is the role that formal risk analyses play in this process. Does a detailed analysis of the risks promote reasoned debate by allowing the protagonists to identify points of disagreement, or does a risk analysis inhibit debate by the use of sophisticated, and often difficult to understand, methodologies?

It is also important to investigate the costs of the proceedings. An open process is expensive in terms of the time lost to participants, the hearing costs and the volumes of reports generated by the many interest groups. One is tempted to add delays to this list, but the role of delay is ambiguous. Whether the time lost in siting a large-scale facility is indeed a cost depends on the immediacy of the need, the alternatives, and the contemporaneous desirability of the project. Delays allow time to reflect as well as time to discover new alternatives.

On a final level, it is important to ask if the process can be improved. Are the procedures leading to the selection of a site for an LEG terminal appropriate in terms, inter alia, of their accessibility to the public, their potential for early consideration of alternatives, the avoidance of unnecessary delays, and a total increase in national welfare?

TOPICS FOR DISCUSSION

In what follows, we will be presenting the problems and unanswered questions that have emerged from our interviews. The problems presented here should serve as a guide to the types of discussion we hope to have in each of the sessions. The questions and issues are grouped under the heading of each session.

What follows amounts to a simplified catalogue of the myriad questions and issues so far identified. For the Task Force Meeting to be productive, it should focus on some key subset of these issues. Participants will have their own lists of key issues and this can aid the clear definition of the overall problem pattern.

One procedural problem is that the issues presented here are written as general issues, while, of course, each country and each country's siting process is different. It is the participants' special knowledge that can help identify aspects of processes common across countries. This can be done in two different ways:

1) by making statements about siting processes that are true in several countries,

2) by identifying measures to describe siting processes that apply in several countries, though each country might score differently on any given measure

The lists of questions and issues that follow are not exhaustive. It is hoped that the participants will feel free to add their own ideas.

I. OVERALL PROBLEM STRUCTURE

The IIASA group will begin by laying out an overall representation of the LEG siting problem. This will create the framework necessary to organize the issues and motivate debate. The elements of the structure will include the alternatives considered, the decisions faced, the participants in and groups affected by those decisions, and the objectives and tradeoffs of those participants. The problem structure will attempt to represent the various ways the interested parties interact and are represented in various types of hearings, courts, legislation, media, polls, political processes, etc. One of the foci will be the role that technical, economic, and risk analyses play in the overall process. To make the problem structure more concrete, the IIASA group will demonstrate how one or two case histories fit into the framework.

II. REPRESENTATION, EQUITY, AND THE ROLE OF TECHNICAL, ECONOMIC, AND RISK ANALYSES

Analysts are interested in the siting of large scale plants in terms of the role played by technical, economic, and especially here, risk analyses. Prescriptive siting analyses can be made broad enough, it is suggested, to include the important societal concerns and the value tradeoffs involved. The particular focus of the present research is the role risk analyses play in facility siting: how the analyses are done, what improvements could be made accounting for differences between nations. However, numerous interviews with the participants in LEG facility siting processes have shown that technical, economic, and risk analyses often do not play a clear, unambiguous central role. The actual process is often best described as political, and not particularly sensitive to the results of analyses as they are presented. The role of analyses is often subtle, and hard to identify in the midst of a decision process with several interested parties. Acknowledging, then, the political nature of the process, study of the role of analyses seems appropriate.

The analyses or processes that can be brought to bear on LEG facility siting can be divided into three categories:

1) purely technical analyses can provide useful information for siting, but may not be effectively incorporated in the actual siting decision process,

2) purely political processes may site facilities in a way that is only very subtly related to technical analyses,

3) broad prescriptive analyses try to bridge the gap between the other two by incorporating in a structured way societal concerns and value tradeoffs into a prescriptive analysis that includes technical information.

While the third category seems promising, it may be rather difficult. To account adequately for the realities of the political process (inconvenient institutional boundaries, special sensitivities to particular groups and overlapping mandates) will not be simple. There is, thus, much room for debate as to what sort of technical or prescriptive analyses can be made effective in a political process. Viewed differently, what features of a political process allow adequate consideration of technical or prescriptive analyses? Specific topics that could be touched are as follows.

A. Representation of All Interests in the Overall Decision Process

The process can be represented as the interaction of several interested parties. Each party may have different tradeoffs among the objectives involved (cost, supply security, safety, environmental quality, etc.). How is each of those parties represented in the process? More specifically: How are the decisions made sensitive to the tradeoffs among objectives presented by each of the interested parties? In studying the debates over need for LNG in the US, the question arises: To what extent are differences in the stands of the various interested parties due to differing tradeoffs among the objectives, as opposed to differing opinions as to what is likely to happen in the future? One key issue in an international comparison of siting procedures is the degree of centralization. What sort of policies result from decentralized processes, where each decision-maker has different tradeoffs among the objectives? How do decentralized processes compare with centralized, or "one-stop licensing" processes?

B. Equity Considerations

Closely related to the above is the balancing of the representation of interested parties in the final decision. Two aspects emerge: how the conflicting arguments of the various interested parties should be weighed; and how the differential impacts over the various parties should be weighed. If in an existing siting process particular interests are over or under represented, how can that be determined? How can that be remedied?

C. Role of Technical, Economic, and Risk Analyses

It is one thing to muse that sometimes technical, economic, and risk analyses do not seem to play much of a role. It is quite another to make substantial statements concerning the appropriate nature and size of that role; whether the observed role is too large, too small, or appropriate; or how best to change the size and nature of the role of analyses if it is inappropriate. Various questions can be raised to aid in the generation of such statements: How is the existing technical information employed in the process? How well could the outcome of the process be defended on analytic grounds? If analyses play a small role, and that is viewed as appropriate, why? If analyses play an inappropriately small or large role, why? How could that best be remedied? Could the political process be changed in an appropriate, incremental, and feasible way to make more appropriate use of analyses? How could analyses be improved to better serve the siting process?

III. THE RELATIONSHIP BETWEEN NATIONAL ENERGY POLICY AND LEG SITING POLICY

To understand the role of LEG in a country's energy mix, it is necessary to understand the mechanisms determining the relative importance of alternative energy supplies. On the one extreme, the energy mix can be a result of market mechanisms allowing industry sole responsibility for forseeing needs and meeting these needs with their own initiatives; on the other extreme, this mix can be a result of a detailed government energy plan fulfilled by directives to nationalized industries. None of the countries selected for our case studies represents either of these extremes. They do represent a wide range of emphasis on private initiative versus centralized planning for future fuel supplies. Since the manner in which the import/export of LEG is promoted in an economy is dependent on the interaction between government and industry, it is important to understand the role of government energy planning in the countries under study. More specifically, for each country we shall be asking the following:

-- Who conceives an L.E.G. import/export project? Does industry take the initiative, or do plans for the project first arise in the context of a national (regional) energy plan? Or, is there some combination of both? Should the present emphasis be changed?

-- Where industry takes the lead, to what extent does, and should, approval depend on national (regional) energy policy?

Page 8

- Where there exists a national (regional) energy plan, what attributes of the energy sources, including cost, environmental effects, security of supply, effects of low- or high-technology, safety, etc., are taken into consideration? How is the relative importance of each of these attributes determined? Is this weighting appropriate? How much weight is, or should be, given to local economic and environmental factors?

- How are demands for energy use forecasted? In what way are the safety aspects considered? Are both high- and low-energy use scenarios considered? What changes would be helpful?

- What is the role of technical analyses in formulating these plans? Should they be put to more or to less use?

- Where there is inter- or intra-agency disagreement on the above, how are these disagreements resolved? Can this process be improved?

- How are regional or national energy strategies introduced into local siting processes? Can this procedure be improved?

- To what extent, and at what stage in the process, is the public involved? Is there open debate on all the underlying issues? What improvements are needed?

- What role does industry play in drawing up a comprehensive energy plan? Does industry provide the supply data, the demand data, the technological information, etc? Does industry participate in hearings on the plan? What role should industry play?

- What real effect does the energy plan have on actual policy, on policy with regards to L.E.G.? Should it have more or less influence?

- Where there is local opposition to the regional or national plans, how is this conflict resolved? Who decides if a local government is reasonably protecting its rights or if it is obstructing national interests? Who should decide?

- In what ways could participation between industry and government to approve or to disapprove an L.E.G. project be improved? Is more, or better, government planning needed? Is more private initiative needed? Why?

- Where there does not exist a comprehensive energy plan (national or regional), should there? Where there does exist such a plan, in what ways can it be improved?

IV. THE DIFFERENT POINTS OF VIEW

A. The Views of the Interested Parties

An important lesson from our research to date is that there is no simple decision structure that describes the siting process. It has become clear that a central factor in understanding the problem of managing technological risks is recognizing the complexity of the decision structures involved.

Each interested party views the problem from a different perspective, and so brings a different structure to the problem. The industry involved may view the siting problem as a choice among alternative investments, where such factors as net return on capital and energy-supply security are primary concerns. Local interest groups may view the problem as one of trading safety for jobs and a health local economy, or perhaps as a land-use problem. Some interest groups may consider the problem as one of protecting natural resources. Government planning agencies may be concerned with compatability between siting plans and their long-term land use plan. Regulatory agencies may view the problem in terms of public safety, energy supply security, and the economics of the project (reasonable price for the ratepayer, etc.).

Each of the expected participants at our Task Force Meeting is personally involved in the L.E.G. siting issue in his respective country. Each view's the problem from a perspective unique to his country, and to his affiliation or level of involvement, and thus each brings a unique structure to the problem. We are interested in hearing more about these many different perspectives, in learning about the problem from the point-of-view of those most directly involved. More specifically, we would like to find out:

-- how each participant defines the siting problem and how each describes the process leading to, or having led to, its resolution;

-- what each participant has learned from the past events, and

-- what changes each participant would like to see in the process so that problems of the past can be avoided in the future.

B. An Industry View of Terminal Siting

Though there are many differences among countries in the perception industry has of the LEG siting problem, from our interviews some themes have been found to be recurrent. Generally, industry views the siting question as one of finding the lowest cost site feasible in terms of berthing conditions and yet a site that is acceptably safe. The safety of the technology is not of primary concern since industry considers the engineering to be exceptionally good and the risks to the public to be acceptably low. Industry generally supports its case with arguments emphasizing the need for imported natural gas and its desirability as a clean burning fuel. Some common concerns of industry have included the role of local and national regulators and their potential to delay a project, the "red tape" involved in obtaining the numerous permits as well as overlapping mandates among the relevant authorities, the over representation of local interest groups at the expense of the national interest, the absence of a clear national policy for siting, the lack of contract security with the L.E.G. supplying country, and the list could continue.

The IIASA task group is especially interested in those issues industry views as relevant to the siting problem. The following questions are posed to serve as possible guidelines to the discussion:

-- How does industry view the siting problem--as an investment decision? as a matter of supply security? other?

-- Where industry takes the initiative, how does it proceed in selecting a site for an import terminal? What factors--economic, environmental, safety--are taken into consideration? How many sites are screened? How many alternative sites are generated? How can this process be improved?

-- Where supply security is a concern, what weight is this security given relative to financial costs, to environmental costs, and to public safety?

-- How does the approval process proceed? Is it satisfactory, or are there unreasonable "red tape" and delays?

-- To what degree does the public participate? Is this participation productive? Why or why not?

-- Who has final approval of the import project, of the site? Where there are several levels of government should there be regional or national preemption on environmental and siting issues? How much influence does the local community have on the siting question? How much should it have? Should the approval processes be consolidated?

-- Does the government set incentives for natural gas use, including pricing and tax policies? Are these measures appropriate?

-- What role do technical and economic analyses, especially risk analyses, play in the approval process? What types of analyses with regard to their content, format and presentation are best suited for promoting informed and intelligent debate? Are probabilities and uncertainty incorporated into the decision processes in a satisfactory manner? How can this process be improved?

-- How is the acceptability of the safety risks to the public established? Is it meaningful to express safety in terms of annual probability of death per person? Should these probabilities be compared with the risks from natural hazards or from other technologies?

-- How should disagreements over the probabilities be resolved? Can more appropriate alternatives for deciding the acceptability of a technology be imagined?

C. A Local View of Terminal Siting

One of the most notable findings of our investigations is the wide variations in local support of, or local opposition to, planned LEG facilities. In some instances, fervent and vocal opposition groups have arisen to fight industrial siting plans. Without exception, these groups have not been opposed to the import/export of LEG, per se, but to the particular site selected for the terminal. In other instances, the local population appears to support the site. These extremes invite many questions including:

-- What are the reasons behind these two extreme views? Do local populations supporting facilities view these facilities as safer than those populations opposing them, or do they perceive the benefits (employment, tax revenues, lower-priced gas,...) as outweighing the possible risks? Or is the absence of opposition simply a result of lack of interest and/or lack of knowledge of the planned project?

-- Where there are strong interest groups opposing the technologies, what are their stated and unstated motivations? How do they view the problem? Are risks of primary concern, as is usually purported, or is environmental degradation and the resulting declines in local property values of overriding concern? How are the possible benefits, including local jobs and increased economic activity, assessed?

-- How do these groups perceive the risks? Where do they get their information? With whom are they in contact? Are their views reasonable?

-- Do these groups feel adequately represented in the decision process? How might this process be improved?

-- How do the members of opposition groups and members of support groups view the use of formal, technical analyses? Are these analyses useful for promoting informed debate or detrimental in the sense of fogging the issues with sophisticated mathematical methodologies?

-- Can uncertainties be debated at an open forum? Why or why not? How is the acceptability or nonacceptability of public safety hazards determined? How should it be determined?

-- Why are local opposition groups usually reluctant to form coalitions with national or global groups opposing, in a more general sense, the use of different forms of L.E.G.?

D. A Societal View of Terminal Siting

An interesting finding from our interviews is a general lack of participation by national or global groups interested in the short- and long-range implications of introducing high-technology L.E.G. import facilities. In several cases, such groups have reported a strong concern over the safety implications of these operations, but because of higher priority given to the nuclear questions, there has been a lack of staff and money to participate actively in L.E.G. matters. This brings up a number of questions:

-- How do these groups view the siting problem? What are their demands? What alternatives do they perceive?

-- Should these broader based groups receive governmental funding? Why or why not?

-- How do these groups view the decision process? Do they have adequate opportunity to participate and real authority to influence the outcome? How can this process be improved?

-- Where do these groups get their information? To what use can formal, technical analyses be in making their case heard? How do they view the role of "experts"?

-- Do these groups have a broad public support, including representation of the underrepresented (non-residents, poor, future generations), or are they overrepresented?

-- What tactics are available to them? Is "delay" a legitimate tactic?

-- How do societal interest groups view the role of government, of industry, of local opposition groups?

E. The Regulators' View of Terminal Siting

Another highly variable feature across our selected countries is the degree of centralization of the decision network. In some countries, hundreds of permits and approvals are necessary to site a facility; in other countries, the decision rests in one central agency. There are obvious advantages and disadvantages to either case, and it is intriguing to ask how satisfied are the authorities with their respective systems. Along this line, we can ask the following:

- How many agency approvals are required for an L.E.G. terminal to be sited? Can local authorities be preempted by regional or national governments? Is this high- or low-degree of centralization desirable?

- How do the regulators view the siting problem? as a question of regulating facility design and fuel prices? as ensuring public safety? as a long-range planning problem?

- What factors do the regional or national governments take into account in approving an L.E.G. import/export project? in approving or turning down an applicant for a site? What weights are given these factors? Are these weights appropriate?

- What are the dynamics of the process in terms of <u>when</u> decisions are taken, <u>when</u> intervenors are heard, etc.? Should this dynamic be in any way changed?

- Are effective and timely decisions hampered by overlapping mandates, by inefficient procedures, by excessive bureaucratic requirements?

- What role do the courts play in the decision process?

- How do the authorities view the system in terms of its fairness and effectiveness? Is adequate (or excessive) representation given to all interested parties? What improvements are necessary?

- How representative is the policy process? Can siting decisions be made by more or less popular procedures including open hearings, referenda, and so forth? What degree of participation is practical?

- How legitimate is the process as viewed by industry, by local interest groups, by the public?

- How can the process be improved?

V. FUTURE DIRECTIONS FOR SITING DECISIONS

Looking to the future, it is essential for the IIASA group to ask how the process of siting an LEG facility, or any large-scale energy facility, can be improved in each of the countries under study. In the above sections, we have stressed the need for each participant to reflect on his experiences so that he can express his views on how things might be improved in the future. In this section, we hope to bring together the most important ideas generated in the foregoing and to develop these ideas from the perspective of the several participating countries.

Though the themes yet to be discussed will certainly develop from prior discussions, there are a few themes which, from our interviews, appear to be likely candidates. One concerns the degree of autonomy that industry enjoys versus the amount of central decisionmaking that exists to fulfill energy needs. A second topical issue concerns the level of government that is charged with making the siting decision, the question of national interest versus local autonomy, as mentioned above. The degree to which local governments can determine the use of their coastlines varies over the countries being studied. A third candidate, which has been a recurrent theme in the above is the use that can be made of technical-economic analyses, including cost-benefit, risk-benefit, environmental impact and risk assessment, in the policy process. In some cases, it seems that the formal risk analyses played a decision role, which appears to have been affected by the format chosen, e.g., a worst-case scenario, and in other cases, risk analyses seem to have played a more limited role. The following questions relate to these possible foci:

-- Can one speculate on the optimal mix of government planning for energy supplies versus private initiative to fulfill demands? What can be learned from the experiences of countries with differing emphases on planning versus private enterprise? What appears to have worked best for LEG facilities? from whose perspective?

-- Can the government set incentives that direct the economy towards a particular energy-use scenario? Why or why not?

-- Can local autonomy be inconsistent with getting a facility sited? How should the local-interest versus national-interest conflict be resolved? Are compensation plans feasible?

-- What types of analyses are best suited for promoting informed and intelligent debates?

-- How should the results of these analyses be presented in the hearing, or other, procedures? What format describes uncertain outcomes in a manner sensitive to social values and what format is most apt to be acceptable and useful to the process?

-- Can accident risks, and the uncertainties surrounding the estimates, be incorporated into the advocacy process? How can professionals and lay people debate safety issues which involve very low probabilities?

-- Who should assess the safety of a technology? Do existing reports reflect the biases of those requesting them? Should they be subject to review by an outside, independent agency?

-- Besides the risk of death and injury, what other characteristics of the risk from L.E.G. facilities, including the involuntary nature of the risks and the short-term and possibly catastrophic nature of the consequences, influence its perception by the public? Are these perceptions likely to change or to intensify as the debate becomes more publicized? Would comparisons with other large-scale technologies be meaningful?

-- How should the "acceptability" of a risk be determined? Is it meaningful to compare the risk of death from a technology with the risk of death from natural hazards, from other technologies? Perhaps, more importantly, who should decide on the acceptability of risks imposed by a technology--the experts? the regulators? public-interest groups? those to whom the risks are imposed?

IN CLOSING

The Working Style of the Task Force Meeting cannot be emphasized enough. It should be clear after reading this paper, that we have more questions than answers. We are counting on the participants to help us elaborate our embryonic structuring of the problem, to keep the focus on the more important practical issues, and to develop policy relevant recommendations that address those issues.

APPENDIX C

LIST OF PARTICIPANTS*

Dr. William Ahern
Public Utilities Commission
350 McAllister Street
San Francisco, CA 94102
USA

Mr. Anthony C. Barrell
Health and Safety Executive
Hazards Assessment Unit
25 Chapel Street
London NW1 5DT
United Kingdom

Mr. Niall Campbell
Assistant Secretary
Scottish Development Department
New St. Andrew's House
Edinburgh EH1 3SZ
United Kingdom

Dr. C.D.J. Cieraad
Centre for Energy Studies TNO
P.O. Box 342
7300 AH Apeldoorn
the Netherlands

Dr. Louis A. Clarenburg
Director
Environmental Care
Public Authority Rijnmond
Vasteland 96-104
3011 BP Rotterdam
the Netherlands

M. Philippe Cruchon
Chef du Service
Service du Gaz
Direction du Gaz
de l'electricite et du charbon
Ministere de l'Industrie
3, rue barbet de Jong
75011 Paris
France

Mr. Norbert Dall
Executive Director
Alliance for Coastal Management, Inc.
1225 Eight Street
Suite 285
Sacramento, CA 95814
USA

Mr. Randolph Deutsch
Principal Counsel
Public Utilities Commission
350 McAllister Street
San Francisco, CA 94102
USA

Dr. Ralph Keeney
Woodward-Clyde Consultants
3 Embarcadero Center
Suite 700
San Francisco, CA 94111
USA

Dr. Sally M. Macgill
Department of Geography
University of Leeds
Leeds LS2 9JT
United Kingdom

Dr. Y. Maksimov
c/o Academician J.M. Gvishiani
Committee for Systems Analysis
Presidium of the Academy of Sciences of the USSR
29, Ryleyev Street
Moscow 119034
USSR

Mr. P.D. Mehta
Aberdour & Dalgety Bay Action Group
Barns Cottage
Aberdour
Fife
Scotland
United Kingdom

*Addresses are effective as of December 1981.

Mr. Robert G. Norton
Vice President
Engineering Department
Distrigas Corporation
125 High Street
Boston, MA 02110
USA

Dr. Y. Oseredko
c/o Academician J.M. Gvishiani
Committee for Systems Analysis
Presidium of the Academy of
Sciences of the USSR
29 Ryleyev Street
Moscow 119034
USSR

Dr. Harry Otway
Joint Research Centre
Commission of the European
Communities
ISPRA (VA)
Italy

Dr. Jerry Ravetz
Department of Philosophy
University of Leeds
Leeds LS2 9JT
United Kingdom

Dr. Lucas Reijnders
Stichting Natuur en Milieu
Donkerstraat 17
3511 KB Utrecht
the Netherlands

Dr. Werner Salz
Bundesministerium fuer Forschung
und Technologie
Heinemannstrasse 2
D-5300 Bonn 2
Federal Republic of Germany

Mr. Jaap Schwarz
Policy Analysis
Staffgroup Strategic Surveys TNO
Complex Apeldoorn
Postbus 541
7300 AM Apeldoorn
the Netherlands

Dr.-Ing. Klaus Schwier
Geschaeftsfuehrer
Ruhrgas LNG
Fluessigerdgas Service GmbH
Huttropstrasse 60
4300 Essen 1
Federal Republic of Germany

M. Robert Vincent
Deputy Head
Product and LEG Department
Gaz du France
Direction de la Production
23 rue Philibert Delorme

IIASA STAFF

Mr. Hermann Atz
Management & Technology
Risk Group
IIASA
A-2361 Laxenburg
Austria

Dr. David Bull
Schneggenstr. 24
8620 Wetzikon ZH
Switzerland

Dr. Howard Kunreuther
Management & Technology
Risk Group
IIASA

Dr. John Lathrop
Woodward-Clyde Consultants
3 Embarcadero Center
Suite 700
San Francisco, CA 94111
USA

Dr. Joanne Linnerooth
Management & Technology
Risk Group
IIASA

Mr. Michiel Schwarz
2 Warner House
Priory Walk
London SW10 9RE
United Kingdom

Dr. Mark Sharefkin
Resources for the Future
1755 Massachusetts Ave., N.W.
Washington, DC 20036
USA

Dr. Craig Sinclair
Directorate of Scientific
Affairs
NATO
Brussels 1110
Belgium

Dr. Michael Thompson
Systems and Decision Sciences
IIASA