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The Attitudes of Science Policy, Environmental, and Utility Leaders on U.S. Energy Issues and Fusion

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Preface

The Lawrence Livermore National Laboratory (LLNL) through its Technology Transfer Initiatives Program is dedicated to transferring the results of its research to others who might utilize it. One part of LLNL's responsibilities in the transfer of technology and invention for application by others, including the private sector, is the need to find effective ways to communicate and collaborate with potential recipients. Furthermore, the Laboratory must make every effort to contribute to the understanding of these new and emerging technologies by working with several groups:

- Universities, to stimulate and encourage succeeding generations of scientists and engineers.
- Industry leaders, to understand their needs and modes of operation and to inform them of the Laboratory's research directions and the concomitant areas of technology development.
- The broader public, to sharpen the Laboratory's sensitivity to safety and environmental issues while helping to communicate complex scientific issues in common, understandable terms.

To make LLNL's Technology Transfer Initiatives Program as effective as possible, it is necessary to identify the best methods and channels whereby a two-way flow of communication can occur: on the one hand, the Laboratory identifies needs of potential technology recipients; on the other hand, the recipients become aware of possible extensions or applications of Laboratory research. In the past, technologists from the Laboratory moved into private industry either as employees or entrepreneurs, thus affecting the direct transfer of technology to the private sector, and this is still occurring. However, with the quickening pace of international competition in high-tech fields, it is becoming increasingly important to supplement this direct transfer by building closer relationships between Laboratory technologists and U.S. industry. Yet, it is not intuitively clear how best to proceed. Certainly, as a first step, business leaders and their advisors must be made acutely aware of the enormous resources available to them from the national laboratories, resources that could help the U.S. maintain its competitive edge in science and technology.

Some data already exist: Recent surveys conducted by the Public Opinion Laboratory (POL) of Northern Illinois University have already polled certain policy leaders and advisors to identify their current attitudes and understandings of issues related to biotechnology. Combining data from these earlier surveys with a new survey pertaining specifically to work at LLNL could help us identify effective ways of communicating and collaborating with individuals interested in LLNL research applications. Analyzing data from a calibrated sample would enable us to choose activities whereby the wealth of technology now being pursued at LLNL could be transferred to the private sector and to other laboratories.

One example of basic and applied research at LLNL that has produced major, highly visible scientific and engineering advances has been the research related to controlled fusion energy. Continuing experimentation at LLNL and elsewhere is likely to demonstrate that fusion is a viable, inexhaustible alternative source of energy. Having conducted major fusion energy experiments for over 30 years at LLNL, its scientists and engineers recognized the enormous challenges that lay ahead in this important endeavor. To be successful, it was clear that collaborative efforts with universities, private industry, and other national laboratories would need to be greatly expanded. Along with invention and scientific discovery would come the challenge of transferring the myriad of new technologies from the laboratories to the private sector for commercialization of the fusion energy process and the application of related technologies to yet unimagined new industries and products.

Therefore, using fusion energy research as the focus, the Laboratory's Technology Transfer Initiatives Program contracted with the Public Opinion Laboratory to conduct a survey designed to promote a better understanding of effective technology transfer. As one of the recognized authorities on scientific surveys, Dr. Jon Miller of the POL worked with Laboratory scientists to understand the objectives of the survey. He then formulated the questions, designed the survey, and derived his survey sample from a qualified list developed at the POL, which has formed the basis for other survey panels. This report, prepared by Dr. Miller, describes the basis and methodology of this survey process and then presents the survey findings and some conclusions.

Gordon T. Longerbeam, Director
Technology Transfer Initiatives Program

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The Attitudes of Science Policy, Environmental, and Utility Leaders on U.S. Energy Issues and Fusion

Introduction

Scientific research and experimentation with controlled fusion energy systems has been underway at laboratories in the United States and other nations for four decades. With the basic science becoming widely understood by those directly involved, major experiments are now being planned that will likely verify the feasibility of fusion power and lead to the development of fusion reactors capable of producing electric power by the middle of the 21st century. Yet, there has been little public or media discussion of the current research in this area or of fusion's technological or energy policy implications for the future.

Fusion technology offers a rare opportunity to study the development of leadership attitudes toward a new technology during the period of its development and prior to its commercial application. This report focuses on the current information base and attitudes toward this emerging technology of leaders in the science policy, environmental, and utility fields and people on the congressional science staff.

Even though the decisions to initiate and support current research and development efforts in fusion represent a public policy decision, it cannot

be said that fusion as a component of energy technology is yet an item of political or public discussion or of controversy in any sense. When a new technology emerges that requires governmental support or that impacts on society in a manner requiring the establishment of public policy, the early stages of public policy formulation are confined to discussion and debate among relevant policy leaders and federal decision makers. Fusion research is now at that stage.

If current fusion research efforts produce the expected commercially viable technology, the broader public will become aware of the technology with its promises and its risks, and form judgments about its applicability. But that understanding may not emerge for many years. In the meantime, there will be a growing need to disseminate information about the critical issues of this emerging technology and to expand collaboration between the public and private sectors. To understand how this process works within the democratic structures and traditions of the United States, it is necessary to turn briefly to a description of the formulation of public policy in regard to low salience issues.

A Stratified Model of the Formulation of Science Policy

As a starting point, it is necessary to examine the policy formulation process. As Price (1954) and others observed more than three decades ago, most science and technology policy issues are far too complex to become understood and advocated by the general public. At the same time, it is clear that over the last three decades there has been an increase in public awareness about science policy matters and some increase in that proportion of the public taking an active interest in these issues.

A number of public opinion studies in the late 1940s found that most adult Americans had very little interest in foreign policy issues and that an even smaller proportion displayed enough knowledge for meaningful participation in foreign policy discussions. At this point, Gabriel Almond examined the problem and proposed a stratified model recognizing that only a fraction of the adult

population would display a high level of interest in and knowledge about an area like foreign policy. Almond suggested that in policy areas (such as foreign policy) that do not impact most individuals on a daily basis and require some level of effort to become and remain informed, only a small segment of the total adult population would be willing to invest the necessary effort. He labelled this group an attentive public.

Almond (1950) placed this attentive public in the context of a four-level system, which he characterized as pyramidal in nature (see Figure 1). At the top of the pyramid he placed the decision-makers, the people in the system who have the power to make binding decisions on any given set of policy matters. In science policy, the decision-makers would include numerous legislative, executive, and judicial officers, primarily at the federal level.

Fig. 1. A stratified model of science and technology policy formulation.

At the second level, policy leaders outside the decision-making realm work to formulate policy proposals and alternatives, to study the effects of various policies, and to present the needs of the constituent groups that they represent either formally or intellectually. Rosenau (1961, 1963) noted in his studies of the leadership group in foreign policy that this group is the pool from which decision-makers are most often drawn and that former decision-makers usually become policy leaders in a given area when they have left a decision-making position. Price (1965), Greenberg (1967), Miller (1983a), and Miller and Prewitt (1984) have observed the same process in regard to science policy.

The attentive public represents the third level of the system and is the *de facto* public for most issues in any given policy domain. The attentive public is composed of those individuals who are highly interested in a given policy area and who have the ability and the resources to become and remain informed about that policy area. Miller,

Prewitt, and Pearson (1980) estimated that approximately one in five American adults was attentive to science and technology matters in 1979, and that this proportion had doubled since the late 1950s. By 1983, approximately a quarter of American adults were attentive to science and technology policy [Miller, (1984)].

At the bottom of the pyramid is the much more numerous nonattentive public, who has little interest in or knowledge about a given policy area. While this group is the least likely to participate in the formulation of science policy, there are several points about this stratum of the system that should be noted.

First, this nonattentive group, in a democratic political system, can exercise a veto if there is extensive public disenchantment with the policies or the results of the actions of the decision-makers. The role of the mass public in ending the wars in Korea and Vietnam illustrate the operation of this veto.

Second, when referenda are used to decide science policy issues, the nonattentive public usu-

ally makes the decision. While several studies of nuclear power referenda have indicated that the nonattentive public seeks cues from persons whose opinions they value, there is evidence that these cue-givers are as likely to be persons outside the policy leadership group or the attentive public for science policy as they are likely to come from those strata.

Third, the general issue specialization process is a pluralistic one. Many of the people who are not attentive to science and technology are attentive to other issues. Studies in 1979 and 1981 found that approximately half of the adult population was attentive to one or more public policy issues [Miller, (1983a)].

To understand the formulation of public policy about fusion, it is necessary to focus on the role of the policy leaders in this stratified model. In general, when there is agreement on a given policy between the decision-makers and the policy leaders, the policy is implemented and there is no broader involvement in the policy formulation process. A large number of science and technology policy issues have been handled in this manner in the decades since the Second World War and it is likely that a substantial number of policy matters will continue to be resolved directly between policy leaders and decision-makers.

There are, however, three sets of conditions in which a broader policy involvement becomes likely and it is useful to discuss each of those instances briefly.

First, if there arises a serious disagreement among the policy leaders about a given policy matter, there is often an appeal by the contending sides to the attentive public, asking interested and informed citizens to actively intervene in the policy process by communicating their policy preferences to the decision-makers. The current debate over the safety of fission-based nuclear power illustrates this type of division among policy lead-

ers, with the resultant appeals by various scientific and technology leaders to the public at large.

Second, if there is high degree of agreement among the policy leaders but limited or no concurrence by the decision-makers, appeals to the attentive public are also likely. In the first years of the Reagan Administration, the disagreement between the scientific community and the President over the funding of scientific research and science education illustrates the second instance of broader public involvement in the policy process. Many science policy leaders and scientific and engineering organizations have appealed to their members and friends to enter into the policy process and to communicate views to Congress and to the Administration.

Third, when scientific issues are submitted to electoral referenda, the broadest possible public involvement in science policy is invited. While the instances of this type of public involvement are infrequent, they are far from nonexistent. There have been numerous referenda on the issues of fluoridation, laetrile, and nuclear power. For the future, it is important to note that when there is a substantial public interest in a given scientific or technological issue, the referendum is a recourse in a large number of states.

In looking at the general science policy formulation process, it is clear that policy leaders are an important component. In the case of fusion and its related technologies, science policy leaders will play a major role in the policy formulation process, but other national leaders could play an important role in some issues related to fusion. For example, controversies over the siting of a facility—or the rules for siting—would likely involve leaders of national environmental organizations and of the utility industry. Therefore, a comprehensive evaluation of attitudes and knowledge about technological issues, would need to include policy leaders' opinions not only from science but also from environmental and utility spheres.

The 1936 Leadership Study

In response to the wish to determine current knowledge and future expectations about energy in general and about fusion in particular, a leadership study was designed that would identify leaders and poll them. To examine the attitudes of science policy, environmental, utility leaders, and of congressional science staff, each leadership group was defined and a universe list was constructed from which a random sample of leaders was selected. The leaders selected for inclusion in the study received a letter outlining the purpose of the study and a copy of a report by Miller (1985) reflecting a previous leadership study. About a week after the receipt of the letter, a POL interviewer called each leader and conducted a telephone interview (or set up an appointment for a later interview). In most cases, one or more appointments were made to allow the interview to be conducted at a time convenient to the respondent.

Definitions of Leadership Groups

The first and most critical step in the process was the definition of leadership groups. Since comparable studies of science policy leaders had been conducted earlier by Miller and Prewitt (1982) and by Miller (1985), the definition of science policy leaders used in the previous studies was carried forward to the current study. More specifically, the universe list of persons considered to be science policy leaders for the current study included persons we could identify who:

1. Were officers of national professional or scientific societies or associations;
2. Had testified before a committee of Congress on a scientific or technological issue within the previous two years;
3. Had served on a major executive branch advisory committee for science or technology policy within the previous two years;
4. Had published a book or refereed a journal article on a science or technology policy matter within the previous two years;
5. Were members of the National Academy of Sciences, the National Academy of Engineering, or the Institute of Medical Sciences;
6. Had won a Nobel Prize in a scientific field or a Field Medal (mathematics);
7. Had served as officers or on the board of directors of one of the 100 top science or engineering corporations on the Fortune 500 list; or

8. Were full-time science journalists for a national distribution broadcast or print organization.

An individual's name was entered in the universe list once for each time that he or she qualified; thus some individuals were listed several times while others were listed only once. This procedure weighted the degree of leadership activity. The application of these eight criteria produced a total universe list of approximately 12,000 entries, representing about 4,000 individuals.

To provide information about changes in leadership attitudes, all 281 of the science policy leaders included in the 1981 and 1985 studies were included in the current study. Selected questions from the 1981 and 1985 studies were repeated in the interview for this survey, which provided an indication of attitude change in individual leaders over the five-year period since 1981.

In addition to leaders from the earlier studies, additional science policy leaders were selected from the new universe list described above producing a total of 508 science policy leader interviews for the current study.

The definition and selection of a national sample of utility leaders followed a similar procedure. A universe list was constructed that included the officers and boards of directors of all major utility companies in the United States. From this universe list, a sample of utility leaders was selected and 89 interviews were conducted.

A similar procedure determined a national sample of leaders of environmental organizations. A review from congressional testimony on several environmental issues in recent years provided a first list of national environmental organizations that had presented testimony and appeared to be actively involved in seeking to influence public policy. The groups identified for sampling included the National Geographic Society, the Friends of the Earth, the Conservation Foundation, Environmental Action, the Environmental Foundation, the National Resources Defense Council, the Sierra Club, the National Wildlife Federation, Resources for the Future, the National Audubon Society, the Environmental Defense Fund, the Wilderness Society, and Greenpeace. Efforts were made to identify the approximate size of each of these organizations and a final list of 12 major organizations was compiled. The officers and boards of directors of these organizations constituted the universe list for this segment of the study. A sample was selected and 150 interviews were conducted.

The final group of panelists selected come from those professionals who staff the key science and technology committees of the U.S. Congress. These staff members play a major role in interpreting the myriad of inputs given to congressional decision makers and in converting the data into analytical reports that might form the basis for legislative action. Their attitudes and level of understanding are important in the overall development of scientific policy. A sampling was selected and 96 interviews were conducted.

The Leadership Interview

Each person who participated in the study was interviewed by telephone from the Public Opinion Laboratory at Northern Illinois University, using a computer-assisted-telephone-interviewing (CATI) system. This means that the interview questions are programmed into a micro-processor and the interviewer reads each question from a video display and enters the response into a keyboard. This process allows branching and logical checks to be built into the interview. It is also faster and more accurate than traditional paper and pencil interview forms.

The average interview took about 25 minutes. The interview was scheduled at a time convenient

for the respondent. Most interviews were conducted during normal office hours, but some were scheduled for evenings and weekends. This flexible scheduling approach improves the quality of the interview and the resulting data.

A Profile of the Leadership Groups

An analysis of the demographic characteristics of the leaders included in this study points to a highly-educated, middle-aged group (see Table 1). Three of four science policy and a third of the leaders of national environmental organizations have an earned doctorate. Approximately half of science policy, environmental, and utility leaders are 55 years of age or older, in contrast to the younger congressional science staff.

Within the science policy leadership group, the distribution among disciplines and types of employers demonstrates a healthy diversity. The strong influence of physical scientists had been noted by Price (1965) and others, but the number of engineers, physicians, and other professionals is slightly higher than in previous studies, suggesting increasing leadership recruitment from these groups. The relatively large university representation reflects the domination of major disciplinary groups by university-based scientists

Q: I will ask you a few questions about yourself. What is your highest degree? What is your major field of study? What is your age? Would you classify your primary employer as a for-profit organization, a university, or some other non-profit organization?

Table 1. Demographic characteristics

	Earned doctorate	Age 55 +
Science policy leaders (508)	72%	48%
Discipline		
Biological sciences (92)	85	38
Physical sciences (159)	82	55
Social sciences (72)	82	45
Engineer-professional (119)	61	51
Other (66)	65	48
Employer		
For-profit (91)	44	48
University (249)	90	44
Other non-profit (168)	60	50
Environmental leaders (150)	34	52
Utility leaders (89)	10	57
Congressional science staff (96)	23	13

and engineers. There were no major departures from the profile of science policy leaders found in earlier studies [Miller and Prewitt (1982); Miller, (1985)].

An examination of the professional recognition and activities of the leaders included in this study points to a vigorous and influential group. One in five science policy leaders selected for this study have been elected to the National Academy of Science, the National Academy of Engineering, or the Institute of Medicine (see Table 2). Election to these groups is a signal honor in any profession or discipline and reflects the achievements of these individuals in their professions and disciplines.

Selection for or election to the governing bodies of major educational or research institutions is another indicator of distinguished career achievement. One in five utility leaders, 16 percent of environmental leaders, and 10 percent of science policy leaders currently or have previously served on the board of trustees of a college or university. About one in five utility and environmental leaders have served on the board of directors of one or more independent research centers,

as have 17 percent of science policy leaders. A third of utility leaders and at least 20 percent of science policy and environmental organization leaders have served on the board of directors of a corporation engaged substantially in science or engineering. All of these appointments are symbolic of the achievements of the leadership sample.

A third facet of leadership is reflected in selection for service in national professional and disciplinary organizations and societies. Over 40 percent of science policy leaders reported service on the editorial board of one or more scientific or engineering journals, as did 21 percent of environmental organization leaders. A majority of science policy leaders and 44 percent of environmental organization leaders have served on national committees of professional and disciplinary societies. Thirty percent of science policy leaders have held national office in a professional or disciplinary society as have 26 percent of environmental organization leaders. In short, the individuals selected for inclusion in the leadership sample have a strong record of professional achievement and recognition.

Q: *Let me read you a list of groups and organizations; which of these do you belong to?*

- A National Academy of Sciences, or
National Academy of Engineering, or
Institute of Medicine*
- B On board of trustees of a college or university*
- C On governing board of any center or laboratory engaged in scientific research or development*
- D On board of directors of any corporation involved in science or technology*
- E On editorial board of a scientific or technological journal*
- F National officer of a professional or disciplinary society*
- G National committee of a professional or disciplinary society*

Table 2. Leadership recognition and activities

	A	B	C	D	E	F	G
Science policy leaders (508)	18%	10%	17%	22%	44%	30%	56%
Discipline							
Biological sciences (92)	20	5	10	16	55	31	55
Physical sciences (159)	18	9	24	27	46	33	62
Social sciences (72)	15	5	15	12	41	21	45
Eng./professional (119)	23	13	17	31	43	35	65
Other (66)	8	16	14	12	20	18	35
Employer							
For-profit (91)	23	22	21	34	30	24	60
University (249)	19	5	20	21	55	35	60
Other non-profit (168)	12	8	10	15	36	26	48
Environmental leaders (150)	7	16	21	23	21	26	44
Utility leaders (89)	1	21	19	34	3	6	19
Congressional staff (96)	1	2	1	2	5	9	18

Expectations, Concerns, and Policy Attitudes

One major focus of this study was the energy policy attitudes and preferences of relevant leaders. To understand policy attitudes, however, it is necessary to begin with an examination of expectations for future developments in energy-related research.

To probe longer-term expectations, each leader was asked to name the primary, secondary, and tertiary energy sources for the United States in 50 years. A majority of science policy and utility leaders cited nuclear power as the primary energy source 50 years from now (see Table 3). An additional 40 percent of utility leaders and 31 percent of science policy leaders named nuclear power as the second most important energy source 50 years in the future. In contrast, a third of environmental organization leaders and congressional science staff thought that nuclear power would be the primary source in 50 years, although at least 60 percent of both groups named nuclear power as one of the two most important future sources.

While the original question did not specify the kind or source of nuclear power, a follow-up query asked each leader to indicate whether 50 years from now nuclear power would be produced by fission-based or fusion-based processes. Over 40 percent of utility leaders and 38 percent of science policy leaders responded that they expected that nuclear power would be based on a fusion process. Thirty percent of environmental organization leaders indicated an expectation that

the fusion process would be the basis for future nuclear power, but a large portion of this group reported that they did not know enough about the work in the area to make a reasonable judgment (discussed later in Tables 26 and 27).

There is also a considerable amount of optimism about solutions to current energy technology problems. At least three-quarters of each leadership group expressed the view that it was very likely that a method would be developed in the next 20 years for the removal of sulfur from the emissions of burned fossil fuels. Three-quarters of utility leaders and 44 percent of science policy leaders think that it is very likely that a safe method for the long-term storage of radioactive wastes will be developed in the next 20 years, but only 27 percent of environmental organization leaders share that view.

Finally, even though there is substantial leadership expectation that fusion-based power will be a major energy source for the United States in 50 years, there is less optimism that the technologies necessary for commercially viable fusion power will be ready within the next 20 years. Only 18 percent of utility leaders and 13 percent of science policy leaders thought that the necessary technologies could be developed within the next two decades (see Table 3).

Focusing on the present, at least 70 percent of science policy and utility leaders conclude that the benefits of current nuclear power outweigh its

Q: Now, think about the future (20 to 50 years from now) and consider some of the potential outcomes of science and technology. Do you agree with the following outcomes?

- A Nuclear power will be the primary U.S. energy source in 50 years.*
- B Nuclear power will be the second most important U.S. energy source in 50 years.*
- C Nuclear power will be the third most important U.S. energy source in 50 years.*
- D Technology for nuclear power in 50 years will be based on fusion process.*
- E A method to remove sulfur from fossil fuel emissions will very likely be developed within 20 years.*
- F A safe method for long-term storage of radioactive wastes will very likely be developed within 20 years.*
- G Technologies for clean and inexpensive fusion energy will very likely be developed within 20 years.*

Table 3. Expectations of future developments in energy

	A	B	C	D	E	F	G
Science policy leaders (508)	51%	31%	15%	38%	74%	44%	13%
Environmental leaders (150)	32	28	17	30	78	27	17
Utility leaders (89)	59	40	12	43	87	74	18
Congressional science staff (96)	31	40	15	37	75	43	16

risks, a view shared by 77 percent of congressional science staff (see Table 4). Environmental organization leaders are evenly split on the issue, with 50 percent expressing the view that the benefits exceed the risks and 49 percent taking the opposite view. Are these expectations and concerns expressed in specific policy attitudes? Another major focus of the study was the identification of attitudes relevant to energy policy.

Looking at a set of near-term policy options, there is broad leadership consensus (see Table 5). Over three-quarters of science policy and environmental leaders agree that there will be serious long-term environmental damage if the present usage of fossil fuel continues. Utility leaders dissent from this view, with only 38 percent agreeing that long-term environmental damage is likely to occur. Over 90 percent of science policy and environmental leaders favor placing a high priority for both government and industry on reducing and eliminating acid rain. Three-quarters of utility leaders share this view. More than 90 percent of all groups agree that given the finite supply of fossil fuels, it is important to begin planning now for the time when fossil fuels will either be severely limited or not available. There is a similar consensus that all industrialized countries should seek to reduce their use of fossil fuels and that the United States should seek to reduce its dependence on foreign energy sources.

There is also substantial agreement that fusion-based processes are the best long-term source of electrical energy. Over three-quarters of utility leaders and 60 percent of science policy leaders agree that fusion is the best hope for the long run. In contrast, only 44 percent of environmental organization leaders and 45 percent of congressional science staff were willing to label fusion as the best long-term hope.

In summary, the results from this study suggest that there is considerable common ground among the leadership groups about current and future energy policy. Looking to the longer-term future, there is broad agreement that nuclear power will be a major energy source in 50 years, and a substantial portion of the leaders think that this will be fusion power. There is also a high level of optimism that some of the safety and pollution problems associated with current energy sources will be solved within the next 20 years. A majority of leaders believe that the current benefits of nuclear power exceed its risks and that the continued burning of fossil fuels in the atmosphere will result in long-term environmental damage. There is strong support for planning now for the time when fossil fuels will be largely unavailable and for seeking a planet-wide reduction in the use of fossil fuels. Science policy and utility leaders believe that fusion holds the best prospects for a long-term source of electrical power.

Q: Many current issues in science and technology may be viewed as a judgment of relative risks and benefits. Thinking about the use of current nuclear reactors to generate electricity, there is broad agreement that there are some risks and some benefits associated with nuclear power. In your opinion, would you say that the risks are greater than the benefits, or that the benefits are greater than the risks?

Would you say that the benefits are substantially greater than the risks, or only slightly greater than the risks? Would you say that the risks are substantially greater than the benefits, or only slightly greater than the benefits?

Table 4. Risk-benefit assessment of current nuclear power

	Risks		About equal	Benefits	
	Much greater	Slightly greater		Slightly greater	Much greater
Science policy leaders (508)	19%	7%	3%	19%	52%
Environmental leaders (150)	39	10	1	19	31
Utility leaders (89)	2	0	2	8	88
Congressional science staff (96)	14	9	0	22	55

Q: Now, I will read you some statements about current science policy issues. Do you agree with the following statements?

- A Continuation of present fossil fuel use will cause serious long-term environmental damage.
- B U.S. government and private industry should place high priority on reducing and eliminating acid rain.
- C Given the finite supply of fossil fuels, it is important to plan now for the time when supplies are limited or not available.
- D Important for U.S. to decrease its dependence on foreign energy sources.
- E Important for all industrial nations to reduce their dependence on fossil fuels in the next 50 years.
- F Commercial development of nuclear fusion offers best long-term source of electrical energy.

Table 5. Attitudes relevant to energy policy

	A	B	C	D	E	F
Science policy leaders (508)	77%	95%	94%	87%	90%	60%
Environmental leaders (150)	82	91	93	81	88	44
Utility leaders (89)	38	75	91	90	77	77
Congressional science staff (96)	61	90	93	88	81	45

Leadership Assessment of International Competition

Science and technology are international: scientists and engineers share journals, professional organizations, and research facilities, and scientists world-wide exchange ideas readily. Yet, the benefits of selected technologies tend to flow most strongly to those nations whose scientists or engineers are able to create and patent commercially viable processes. Policy leaders rejected nearly 2:1 the concept that the pursuit of patents by industrial and university researchers in the U.S. has had negative effects (see Table 6). At the same time that they appreciate the value of patenting technology, there is near unanimity that a nation's economic growth is closely related to its investment in basic scientific research (see Table 7).

There is also substantial agreement that pressure to convert basic scientific research to commercial applications has a positive effect on the research process (see Table 8). When asked how commercializing areas of science would affect public confidence, there was general agreement that public confidence would be increased by such efforts (see Table 9). Finally, whether related to technology transfer or simply to strengthening the foundation of U.S. scientific capability, nearly two-thirds of the science policy leaders believe that the public derives benefits from the basic research it pays for (see Table 10).

Q: *Do you think that the pursuit of patents by industrial and university researchers has tended to reduce the openness of the research process and has fostered harmful consequences?*

Table 6. Effect of patents on openness in research

	Strongly agree	Agree	Disagree	Strongly disagree	Don't know
Science policy leaders (508)	5%	22%	49%	10%	7%
Environmental leaders (150)	4	31	38	3	23
Utility leaders (89)	0	28	49	3	17
Congressional science staff (96)	3	23	53	7	14

Q: *Now, I'd like to turn to some questions about basic scientific research. In a few minutes, I will ask you some questions about applied research and development issues, but now I would like you to focus on basic scientific research. First, let me ask about the relationship between the level of basic scientific research and overall economic growth. In your view, is the economic growth of a nation largely determined by its level of basic scientific research, only somewhat determined by its level of basic research, or are the two generally unrelated?*

Table 7. Effect of basic research on economic growth

	Largely determined	Somewhat determined	Generally unrelated
Science policy leaders (508)	41%	53%	5%
Environmental leaders (150)	39	54	5
Utility leaders (89)	54	44	2
Congressional science staff (96)	26	70	4

Q: *In your view, would you say that the pressure to convert basic scientific results into useful applications has a positive effect on the research process, a negative effect, or no effect on the research process?*

Table 8. Effect of pressure to convert research to useful applications

	Positive effect	Negative effect	No effect
Science policy leaders (508)	68%	14%	10%
Environmental leaders (150)	67	16	10
Utility leaders (89)	75	15	6
Congressional science staff (96)	63	15	21

Q: *Would you say that a strong emphasis on commercialization in an area of science would tend to enhance public confidence in that area, erode public confidence in that area, or make no difference in public confidence?*

Table 9. Effect on public confidence of commercialization in an area of science

	Enhance confidence	Erode confidence	Makes no difference
Science policy leaders (508)	45%	19%	28%
Environmental leaders (150)	41	29	21
Utility leaders (89)	64	15	21
Congressional science staff (96)	49	19	29

Q: *Now, let me ask you to think about the process of converting basic scientific knowledge into useful applications. Would you say that, in the U.S., the public is getting the full benefit of the scientific research it pays for, a substantial benefit, a partial benefit, or little benefit from the basic scientific research?*

Table 10. Public benefit derived from basic research

	Full benefit	Much benefit	Partial benefit	Little benefit
Science policy leaders (508)	12%	54%	30%	2%
Environmental leaders (150)	10	50	31	5
Utility leaders (89)	8	48	42	1
Congressional science staff (96)	8	46	41	4

Having established that policy leaders have strong feelings about the importance of basic scientific research, each of the leaders was asked to evaluate which countries they consider to be in the lead in a set of scientific and technological areas, with specific emphasis on energy-related technologies. As a starting point, each leader was asked to assess which country was strongest in basic scientific research and which was second to the leader. An overwhelming majority of all groups indicated a belief that the United States is the international leader in basic scientific research (see Table 11). Over 40 percent of science policy leaders named a western European country as the second strongest in basic scientific research and 30 percent named the Soviet Union. Only 19 percent of science policy leaders cited Japan as the second ranked country in this area.

In fission-based nuclear technology, there is an interesting division of views (see Table 12). Almost half of utility leaders cite western Europe (primarily France) as the leader in this area, while 39 percent cite the United States. In contrast, 51 percent of science policy leaders cite the United States as the leader in fission-based energy technologies and only 26 percent cite western Europe. Congressional science staff tended to reflect the views of science policy leaders.

In regard to fusion-based energy technologies, however, there is broad leadership consensus that the United States holds the lead (see Table 13). About 58 percent of science policy leaders cited the United States as the leader in this area, while 13 percent cited the Soviet Union as the leader. About 45 percent of utility and environmental leaders named the United States as the

Q: Now, I would like you to think about the issue of international competition in science and technology. I will mention several areas of scientific or technological research, and, for each one, I would like you to name the leading country and its closest competitor.

First, which two countries lead in basic scientific research?

Table 11. Countries mentioned in basic scientific research

	USA		USSR		Japan		Europe	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Science policy leaders (508)	90%	3%	1%	30%	2%	19%	2%	41%
Environmental leaders (150)	89	2	1	30	1	27	1	27
Utility leaders (89)	84	5	6	32	1	27	0	25
Congressional science staff (96)	88	4	2	30	3	23	1	33

Q: Next, which two countries lead in fission-based nuclear technology?

Table 12. Countries mentioned regarding fission-based nuclear technology

	USA		USSR		Japan		Europe	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Science policy leaders (508)	51%	8%	3%	19%	1%	3%	26%	34%
Environmental leaders (150)	44	18	3	23	1	3	28	23
Utility leaders (89)	39	26	2	17	0	11	48	29
Congressional science staff (96)	56	20	2	15	1	9	30	38

leader, and about a quarter of each group named the Soviet Union. Over 60 percent of congressional science staff cited the U.S. as the leader in this field. There was broad agreement among all of the leadership groups that the Soviet Union was the second strongest nation in this area.

Finally, with regard to laser technology, which is important in many areas of research including fusion, there was broad leadership agreement that the United States holds a leadership position. Over 70 percent of science policy and utility leaders expressed the view that the United States was first in this area, and the same proportion of congressional science staff concurred (see Table 14). The views of the leaders on the second ranking country in this technology were divided.

About 30 percent of all groups named the Soviet Union while a quarter of science policy and utility leaders selected Japan. Slightly over 10 percent of the three leadership groups cited a western European country.

In summary, the results of the study indicate that science policy, environmental, and utility leaders believe that the United States holds an international leadership position in both basic scientific research and in key energy technologies. Western Europe (especially France) was viewed as being very strong in fission-based energy technologies and the Soviet Union was seen as the next strongest in fusion-based energy technologies.

Q: Next, which two countries lead in fusion-based nuclear technology?

Table 13. Countries mentioned regarding fusion energy research

	USA		USSR		Japan		Europe	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Science policy leaders (508)	58%	17%	13%	42%	0%	2%	6%	11%
Environmental leaders (150)	47	16	12	29	1	3	7	13
Utility leaders (89)	45	21	10	24	0	10	20	15
Congressional science staff (96)	61	16	8	31	2	9	8	18

Q: Next, which two countries lead in laser technology?

Table 14. Countries mentioned regarding laser technology

	USA		USSR		Japan		Europe	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Science policy leaders (508)	72%	6%	3%	27%	2%	25%	0%	13%
Environmental leaders (150)	59	9	3	30	2	14	3	5
Utility Leaders (89)	76	4	1	29	1	31	1	10
Congressional science staff (96)	69	10	4	34	6	27	0	6

Sources of Information About Energy Issues

A major purpose of this study was to examine the information sources used by leaders to learn about energy issues. If a solid program of technology transfer is to be built, it is important to know which sources each leadership group uses most often and which ones are trusted for reliable information on energy matters.

Each leader was asked to name the primary, secondary, and tertiary sources used for information about energy research and development (see Table 15). For science policy leaders, science magazines were the most important source (100 percent), followed by newspapers (44 percent), and professional journals (38 percent). This result parallels a similar finding with regard to current information about biotechnology (Miller, 1985). News magazines and colleagues were reported as important sources by a quarter of science policy leaders.

Among the leaders of environmental organizations, science magazines were the most frequently mentioned source (76 percent), followed by newspapers (56 percent), professional journals (38 percent), and news magazines (35 percent). Nineteen percent mentioned their colleagues.

Science magazines and professional journals were the most used sources by utility leaders, with about half of the utility leaders mentioning each source. Newspapers and news magazines were also important. Television was least important.

To probe information sources, each respondent was asked what sources he or she would use to get additional information on an energy issue seen in a magazine or newspaper (see Table 16). For all of the leadership groups, colleagues were the primary resource. Again, this parallels the result found in the biotechnology survey. Professional journals were the second most important information source for all groups except utility leaders, who indicated a secondary preference for information from organizations.

Viewed in combination, these two sets of data suggest that science magazines, newspapers, and news magazines play an early warning role, alerting a leader to the emergence of an issue or problem. Having become aware of an issue or problem, the leader then turns to a trusted source, which appears to be a professional colleague for most leaders. For utility executives, the source would be an organization.

The study included a set of items designed to look at the information sources in more depth and to assess the relative confidence that leaders have in each of these sources. Table 15 shows that science magazines are an important source of information for the leaders; an analysis of their reading patterns indicates that *Science* magazine is the most widely read among science policy and environmental organization leaders (see Table 17). Among science policy leaders, *Scientific American*

Q: Now, let me ask you how you keep informed about various scientific issues, of how you would find information about a new issues as it emerged. Let's use energy research and development as an example. Thinking back to last year, from what source have you obtained most of your information about energy research and development?

Is there another source that you have also found helpful?

Any others?

A Science magazines	E Television and radio
B News and other magazines	F Colleagues
C Professional journals	G Organizations (meetings, newsletters)
D Newspapers	

Table 15. Sources of information about energy

	A	B	C	D	E	F	G
Science policy leaders (508)	100%	23%	38%	44%	9%	26%	12%
Environmental leaders (150)	76	35	38	56	15	19	11
Utility leaders (89)	51	35	50	38	17	20	24
Congressional science staff (96)	35	35	32	47	12	32	5

Note: Each leader was asked to name up to three information sources, thus the percentages may exceed 100 percent.

is the second most frequently read, followed by a professional journal. Environmental leaders show a similar pattern.

In contrast, utility leaders reported relatively low readership of all of these science magazines. One in five utility leaders reported regular readership of a professional journal in the physical sciences, and 11 percent indicated that they regularly read *Scientific American*.

The readership of more popular science magazines were lower for all of the leadership groups (see Table 18). One in five science policy leaders reported regular readership of the now defunct *Science 86*, but only six percent were regular readers of *Discover*. Nearly a third of science policy

leaders with a background in the physical sciences reported reading *Chemical and Engineering News* regularly.

All of the leadership groups reported substantial patterns of newspaper readership (see Table 18). Over 40 percent of science policy and environmental leaders indicated that they were regular readers of the *New York Times*. In contrast, 86 percent of utility leaders were regular readers of the *Wall Street Journal*, as were 43 percent of environmental leaders and 33 percent of science policy leaders. Fewer than one in ten leaders were regular readers of *USA Today*.

An added dimension in getting information involves the amount of trust or confidence that a

Q: If you were reading an article about energy research and you wanted to get some more information about that issue, how would you obtain additional information?

Is there a second source you would use to obtain additional information?

A Science magazines	E Television and radio
B News and other magazines	F Colleagues
C Professional journals	G Organizations (meetings, newsletters)
D Newspapers	

Table 16. Sources of in-depth information on energy issues

	A	B	C	D	E	F	G
Science policy leaders (508)	4%	2%	15%	1%	0%	52%	10%
Environmental leaders (150)	7	1	11	1	1	38	14
Utility leaders (89)	1	1	2	0	0	32	21
Congressional science staff (96)	6	2	6	1	0	29	16

Note: Each leader was asked to name up to two additional in-depth sources on energy, thus the percentages may exceed 100 percent.

Q: Let me read you a list of science and technology-related magazines and ask you to tell me if you read every issue, most issues, some issues, or no issues of that periodical?

A Science	D A professional journal in the biological sciences
B Scientific American	E A professional journal in chemistry
C Nature	F A professional journal in any other physical science

Table 17. Readership of journals and science periodicals

	Read most issues of ...					
	A	B	C	D	E	F
Science policy leaders (508)	67%	34%	19%	30%	10%	31%
Environmental leaders (150)	33	22	13	28	4	26
Utility leaders (89)	9	11	2	2	4	20
Congressional science staff (96)	27	13	6	7	1	20

reader or viewer places in various media or information sources. To better understand the location of media trust in energy issues, each leader was asked to evaluate the amount of trust or confidence that they would have in selected publications and information sources. The results showed a highly developed structure of trust (see Table 19).

Looking first at science magazines, which, in Table 15, were reportedly the most frequently used source, the results indicate that all three leadership groups have a high level of trust in *Science* and *Scientific American*. Over 80 percent of science policy and environmental organization leaders expressed a great deal of confidence in

those two sources, as did 71 percent of utility leaders and 77 percent of congressional science staff (see Table 19). A substantial, but lower, proportion of leaders expressed a high level of confidence in stories in the *Wall Street Journal* and the *New York Times*. No leadership group placed a high level of confidence in stories in *Time* or *Newsweek*.

Leadership confidence in television appears to be limited to *Nova*, the PBS science magazine show (see Table 20). About four in ten leaders in all three groups indicated that they would have a high level of confidence in information provided by *Nova*, in contrast to fewer than one in ten for

Q: In the following list of science and technology-related magazines, do you read every issue, most issues, some issues, or no issues of that periodical?

A *Science* 86

B *Chemical and Engineering News*

C *Discover*

D *New York Times*

E *Wall Street Journal*

F *USA Today*

Table 18. Readership of selected science magazines

	Read most issues of:					
	A	B	C	D	E	F
Science policy leaders (505)	21%	15%	6%	43%	33%	5%
Environmental leaders (150)	14	5	7	45	43	5
Utility leaders (89)	1	5	6	27	86	13
Congressional science staff (96)	13	15	4	39	46	7

Q: Continuing with the example of energy research and development, I want to read you a short list of organizations and other news sources, and for each one, please tell me if you would have a great deal of confidence, some confidence, or very little confidence in it.

A An article in *Science*

B An article in *Scientific American*

C A story in *Time* or *Newsweek*

D A story in the *New York Times*

E A story in the *Wall Street Journal*

Table 19. Confidence in energy information in selected print media

	A great deal of confidence in:				
	A	B	C	D	E
Science policy leaders (508)	89%	83%	10%	39%	41%
Environmental leaders (150)	82	76	14	45	36
Utility leaders (89)	71	85	21	31	42
Congressional science staff (96)	77	77	13	32	42

either a network news shows or the ABC news show *Nightline*.

Looking at institutional information sources, all of the leadership groups evidenced a high level of trust in information from a "national laboratory like Fermi or Livermore" (see Table 21). About a third of science policy and utility leaders reported a high level of confidence in information from the Department of Energy, but only 18 percent of environmental leaders trusted that source. Only 15 percent of science policy leaders and 18 percent of environmental leaders would place a high level of trust in a report from the Sierra Club, and fewer would trust a report from a utility company. Util-

ity leaders were equally untrusting of a report from a Congressional committee and the Sierra Club.

In summary, science policy, environmental, and utility leaders all expressed a high level of confidence in information published in *Science* or *Scientific American* and in information provided by a national laboratory. The *Wall Street Journal*, the *New York Times*, and the PBS show *Nova* all shared a moderate level of confidence. Participants in overt controversies—utility companies and the Sierra Club—were not trusted by the overwhelming majority of science policy and environmental organization leaders or by congressional science staffers.

Q: Continuing with the example of energy research and development, I will read you a short list of organizations and other news sources, and for each one, please tell me if you would have a great deal of confidence, some confidence, or very little confidence in it.

- A A story on the network television evening news
- B An episode of *Nova* on PBS
- C The ABC news show *Nightline*

Table 20. Confidence in energy information in selected broadcast media

	A great deal of confidence in:		
	A	B	C
Science policy leaders (508)	4%	44%	8%
Environmental leaders (150)	3	46	9
Utility leaders (89)	2	42	4
Congressional science staff (96)	4	45	9

Q: Continuing with the example of energy research and development, I want to read you a short list of organizations and other news sources, and for each one, please tell me if you would have a great deal of confidence, some confidence, or very little confidence in it.

- A A report from a national laboratory like Fermi or Livermore
- B A report from a congressional committee on science and technology
- C A report from the federal Department of Energy
- D A report from a major utility company
- E A report from the Sierra Club

Table 21. Confidence in energy information from selected groups/institutions

	A great deal of confidence in:				
	A	B	C	D	E
Science policy leaders (508)	77%	29%	34%	9%	15%
Environmental leaders (150)	69	27	18	4	18
Utility leaders (89)	96	7	34	56	3
Congressional science staff (96)	78	38	28	8	5

Awareness of and Knowledge About Fusion

A major objective of this study was to determine the level of awareness of fusion among the leadership groups. Two basic approaches were utilized: First, each leader was asked to identify the two most important "public policy issues that involve science and technology." Second, several issues were listed and each leader was asked to classify each issue as a major problem, a minor problem, or not really a problem. Taken together, the two approaches offer important information about leadership perceptions related to fusion.

Looking first at the open-ended inquiries, the results indicate that energy issues are most salient to utility and environmental leaders (see Table 22). In contrast, only 6 percent of science policy leaders and 10 percent of congressional science staff identified an energy-related issue as a high-priority matter in this open-ended context.

When asked about three specific issues, however, leadership awareness of and concern about energy issues increased markedly (see Table 23). At the most basic level, approximately two-thirds of science policy and environmental leaders indicated that they considered "the long-term supply of energy" to be a major problem. Over 80 percent of utility leaders expressed a high level of concern over the long-term energy supply and 64 percent of congressional science staff shared this view.

There was also broad recognition of the environmental problems associated with the burning of fossil fuels (see Table 24). Sixty percent of science policy leaders and 71 percent of environmental organization leaders indicated that they viewed the environmental impact of fossil fuel burning to be a major problem. This concern was shared by 57 percent of congressional science

Q: What do you think is the most important public policy issue that involves science and technology?
What is the next most important public policy issue that involves science and technology?

Key to responses:

A Education	E Military
B Level of research and development	F Energy
C New technology	G Environment and population
D Public understanding of science	H Others

Table 22. Open-ended mention of science-related issue as a first or second priority

	A	B	C	D	E	F	G	H
Science policy leaders (508)	10%	30%	29%	6%	45%	6%	17%	54%
Environmental leaders (150)	4	11	46	5	32	9	32	58
Utility leaders (89)	7	18	27	7	18	10	15	72
Congressional science staff (96)	10	29	29	4	39	22	18	62

Q: Do you think the long-term supply of energy is a major problem, a minor problem, or not really a problem?
Do you feel very well informed, moderately well informed, or not very well informed about the long-term supply of energy?

Table 23. Perception of long-term energy supply as a problem

	Problem		Informed	
	Major	Minor	Well	Moderate
Science policy leaders (508)	69%	25%	42%	49%
Environmental leaders (150)	71	23	47	51
Utility leaders (89)	81	15	81	19
Congressional science staff (96)	64	31	46	47

staff, but only 43 percent of utility industry leaders felt that this was a major problem.

Finally, the leadership groups were divided over the issue of the safety of current nuclear power plants (see Table 25). Half of science policy leaders and 65 percent of environmental organization leaders indicated that "the safety of today's U.S. nuclear power plants" is a major science policy issue. In sharp contrast, only 24 percent of utility industry leaders were willing to call nuclear plant safety a major problem. Forty-four percent of congressional science staff thought that nuclear plant safety was a major issue, while 46 percent of this group classified it as a minor issue.

In summary, looking at the combination of the open-ended and closed-ended items, it appears that energy issues are at the top of the national science policy agenda for fewer than one in ten science policy and environmental leaders and for about one in five utility leaders. When asked about three specific issues, however, all of the

leadership groups agreed that the long-term energy supply was a serious problem and that the continued burning of fossil fuels in the atmosphere would cause environmental damage. There were sharp divisions on the safety of today's U.S. nuclear power plants, reflecting a division noted in several previous studies.

Another major objective of this study was to determine the level of knowledge held by leadership groups about energy issues in general and fusion in particular. This is a difficult task; most adult respondents do not like being "tested" and leaders are even more sensitive about this. Therefore, two different approaches were taken to this problem.

Using an approach previously employed for national attitude studies of adults: Miller, Prewitt, Pearson (1980); Miller (1982, 1983a); Harris (1984), each leader was asked to classify himself or herself as very well informed, moderately well informed, or not very well informed about each of

Q: Do you think the continued burning of fossil fuels in the environment is a major problem, a minor problem, or not really a problem?

Do you feel very well informed, moderately well informed, or not very well informed about the continued burning of fossil fuels in the environment?

Table 24. Perception of fossil-fuel burning as a problem

	Problem		Informed	
	Major	Minor	Well	Moderate
Science policy leaders (508)	60%	37%	39%	50%
Environmental leaders (150)	71	26	58	39
Utility leaders (89)	43	48	64	29
Congressional science staff (96)	57	40	38	52

Q: Do you think the safety of today's U.S. nuclear power plants is a major problem, a minor problem, or not really a problem?

Do you feel very well informed, moderately well informed, or not very well informed about the safety of today's U.S. nuclear power plants?

Table 25. Perception of nuclear safety as a problem

	Problem		Informed	
	Major	Minor	Well	Moderate
Science policy leaders (508)	49%	43%	24%	67%
Environmental leaders (150)	65	31	22	68
Utility leaders (89)	24	47	62	38
Congressional science staff (96)	44	46	29	64

the three issues discussed above (see Tables 23, 24, and 25). In general, a higher proportion of utility leaders than other leaders felt "very well informed" on all three issues, reflecting the focus of their efforts and the depth of their experience. About 40 percent of science policy leaders felt well informed about the long-term energy supply and the impact of fossil fuel burning, but only 24 percent felt well informed about the safety of U.S. nuclear power plants. Environmental organization leaders felt best informed about the burning of fossil fuels and 47 percent felt very well informed about the long-term supply of energy. Only 22 percent of environmental leaders indicated that they were well informed about the safety of current nuclear power plants. Congressional science staff tended to reflect the views of science policy leaders about each of these three issues.

A second approach to measuring leaders' knowledge focused on the self-reported understanding of a set of terms central to energy and fusion technologies. Each leader was asked to indicate whether he or she had a clear understanding, a general sense, or less understanding of each of five energy or fusion-related terms (see Table 26). Utility industry leaders were most likely to understand the operation of a nuclear reactor, with 64 percent indicating that they had a clear understanding of the process. About 45 percent of science policy leaders and a third of environmental leaders reported a clear understanding of reactor operations, as did 42 percent of congressional science staff.

The process of nuclear fission was clearly understood by a higher proportion of all leadership groups than the fusion process, but both processes were understood by a substantial proportion of all groups. Science policy leaders were slightly more likely than others to have a clear understanding of both processes, with 52 percent reporting a clear understanding of fission and 45 percent indicating a clear understanding of fusion. Utility leaders reported comparably high levels, with 47 percent reporting a clear understanding of fission and 43 percent a clear understanding of fusion. Environmental organization leaders were least likely to hold a clear understanding of the terms, with 27 percent indicated that they had a clear understanding of fission and 20 percent a clear understanding of fusion.

Science policy leaders were most likely to understand the "origins and composition of a laser beam," with 32 percent reporting a clear understanding. Only 12 percent of utility leaders and 9 percent of environmental organization leaders indicated a similar level of understanding. Sixteen percent of congressional science staff reported a clear understanding of a laser beam.

Finally, environmental organization leaders were the most likely to hold a clear understanding of the "concept and causes of acid rain," with 79 percent reporting a high level of comprehension. Slightly over half of science policy leaders and utility leaders indicated a similar level of understanding.

Q: There are a lot of new developments in science and technology today. I want to read you a short list of scientific and technological terms and concepts. Do you have a clear understanding of each term, a general sense of it, or less familiarity with it?

- A The operation of a nuclear reactor*
- B The process of nuclear fission*
- C The process of nuclear fusion*

- D The origin and composition of a laser beam*
- E The concept and causes of acid rain*

Table 26. Understanding of selected scientific terms and concepts

	Have clear understanding of:				
	A	B	C	D	E
Science policy leaders (508)	45%	52%	45%	32%	51%
Environmental leaders (150)	33	27	20	9	79
Utility leaders (89)	64	47	43	12	55
Congressional science staff (96)	42	39	32	16	43

To probe the ability of leaders to explain scientific and technical ideas to their colleagues and to the public, the 1986 study asked about the frequency of speeches or presentations to both technical and lay groups (see Table 27). Over 70 percent of science policy leaders indicated that they had given a presentation on a scientific or technical topic to a group of scientists or engineers in the last year and 63 percent reported that they had made a similar presentation to a lay group during the last year. This level of professional and public presentation tends to reflect a high level of self-confidence in their knowledge of substantive issues.

Environmental organization leaders were equally likely to have made a presentation of scientific or technical ideas to a lay audience, but only 41 percent of environmental leaders had made a presentation to a group of scientists or engineers. This pattern may reflect their organizational responsibilities, and suggests a lower level of self-confidence in their ability to explain science and technology issues to technically qualified audiences.

Utility leaders were also more likely to have made presentations to lay than professional audiences, but the overall amount of activity was somewhat lower. The focus on lay groups probably reflects their corporate leadership role. Their corporate duties may also be related to the frequency of presentation, since they are also the managers of large operations. The results suggest, however, that many utility leaders have a sufficient grasp of scientific and technical issues to at-

tempt to explain those concepts to broader audiences.

To probe the understanding of fission and fusion, the study asked each leader if he or she would be able to explain the difference between fission and fusion to a group of corporate board members, if called upon to do so. This type of inquiry and setting was selected since it is typical of the context in which policy discussions often occur and of the type of inquiry often directed to persons thought to be knowledgeable about scientific and technical matters. Slightly over 40 percent of science policy leaders reported that they could give a clear explanation of the difference. Only 31 percent of utility leaders and 22 percent of environmental organization leaders indicated that they could provide a clear explanation of the difference. One in four congressional science staff reported that they could provide this explanation.

In summary, looking at the leadership responses to the items concerning knowledge, it appears that a substantial portion of science policy, environmental, and utility leaders believe that they have a solid information base concerning energy technologies and the science on which they are based. Most of the leaders responded that they are sufficiently confident of their knowledge that they are willing to attempt to share scientific and technical ideas with both professional and lay audiences. On the specific matter of differentiating between fission and fusion, however, a majority of science policy and utility leaders indicated that they could not provide a clear explanation of the difference in a hypothetical board room setting.

Q: Now, let me change the subject and ask you how you might explain certain scientific concepts to your colleagues or to the public. During the last 12 months, have you given a talk or speech on a scientific or technical topic to a group of scientists or engineers?

During the last 12 months, have you given a talk or speech on a scientific or technical topic to a more general audience, that is, one not trained in science or engineering?

If you were talking to a group of corporate board members, most of whom were not trained in science or engineering, would you be able to offer a clear explanation of the difference between nuclear fission and nuclear fusion, a general explanation of this difference, or would you not want to attempt that kind of explanation?

Table 27. Perceived ability to explain scientific concepts

	Gave speech to		Board explanation	
	Technical	Public	Clear	General
Science policy leaders (508)	71%	63%	42%	30%
Environmental leaders (150)	41	65	72	28
Utility leaders (89)	27	43	31	44
Congressional science staff (96)	29	46	25	33

Awareness of National Laboratories

Since a substantial portion of the basic energy research in the United States is conducted in national laboratories, the leaders were asked about their awareness of and contact with these institutions.

Looking first at name recognition, each participant in the study was asked to name the first two national laboratories that came to mind; this technique measures the leaders' familiarity with the names of the national laboratories. Using this approach, Lawrence Livermore National Laboratory was the most frequently mentioned, with 48 percent of science policy leaders and over half of utility and environmental leaders citing it first or second (see Table 28). Sixty percent of congressional science staff mentioned Livermore first or second.

Approximately 30 percent of science policy and utility leaders mentioned Argonne and Oak Ridge National Laboratories first or second. Los Alamos National Laboratory had the second highest name recognition among congressional science

staff. Sandia National Laboratory had the lowest level of name recognition.

In addition to name recognition, the study asked about visits to and contacts with national laboratories. Science policy leaders were the most likely to have visited a national laboratory, with 46 percent reporting a visit within the last two years. A quarter of environmental organization leaders and 15 percent of utility leaders had visited a national laboratory in the same time period. A third of congressional science staff reported a visit to a national laboratory.

Contacts by telephone and letter were more frequent. Fifty-eight percent of science policy leaders reported some contact with a national laboratory within the previous two years, as did 41 percent of environmental leaders and 20 percent of utility leaders. Almost 60 percent of congressional science staff had had some contact with a national laboratory.

In short, there is a reasonably high level of national laboratory visibility among science policy, environmental, and utility leaders.

Q: Now, let me ask you to think about the national laboratories in the United States. When national laboratories are mentioned, which laboratory comes to mind first for you? Which laboratory would come to mind next?

- A Lawrence Livermore National Laboratory
- B Argonne National Laboratory
- C Oak Ridge National Laboratory
- D Los Alamos National Laboratory
- E Brookhaven National Laboratory
- F Fermi National Accelerator Laboratory
- G Sandia National Laboratories

Table 28. Name recognition of national laboratories

	Percent mentioning:						
	A	B	C	D	E	F	G
Science policy leaders (508)	48%	30%	30%	28%	23%	16%	2%
Environmental leaders (150)	52	27	21	28	19	13	1
Utility leaders (89)	56	29	35	10	13	17	3
Congressional science staff (96)	61	15	31	39	11	19	3

Summary and Conclusions

In the preceding sections, we have examined the awareness, knowledge, attitudes, and policy preferences of a national sampling of leaders from the science policy, environmental, and utility fields, and of congressional science staff members. On the basis of those analyses, it is now appropriate to attempt to evaluate the results. Several primary conclusions emerge.

First, a substantial segment of those polled already have some familiarity with the full range of issues about current energy policy. More specifically, there is also a substantial portion of the leaders who believe they have an understanding of the fusion process and who hold the expectation that fusion-based energy technology will be the primary source of electrical power fifty years from now. In this regard, then, we may conclude that there already exists a foundation or basis upon which policy leaders may build an expanded and improved understanding of general energy issues, and of the fusion process and related technologies.

Second, the policy attitudes and orientations of the leaders appear to be positive. Utility leaders show a great deal of enthusiasm for the future prospects of fusion-based energy technologies, as do most science policy leaders. There is discernibly less enthusiasm among environmental leaders and the congressional science staff about long-term prospects for fusion-based systems, but even among these groups there is still substantial support. Among all of the groups, there is a recognition that fossil fuel resources are finite and that it is imperative to plan now for the time when those resources will be gone or severely limited. In broad terms, there is already a forward looking perspective in regard to energy policy.

Third, following a pattern similar to that found in regard to biotechnology, science policy and environmental organization leaders appear to rely heavily on printed media and to focus their trust and confidence on a small number of distinguished publications. We observe a two-step information process. In the first step, leaders use science magazines, news magazines, newspapers, and similar print media to become aware of emerging problems and issues. Once an issue has become visible, a second step of in-depth information acquisition relies heavily on colleagues and disciplinary and industrial organizations.

Finally, the data suggest that there is broad leadership recognition of the importance of better understanding energy policy, long-term energy options, and the associated technologies. There is virtual unanimity among leaders concerning the need to plan for a post-fossil-fuel period, and also a recognition of some of the short-term hazards and drawbacks to current energy technologies. There is a willingness among leaders to consider a wide array of technologies for the production of electricity, and a strong predisposition in favor of fusion-based nuclear technologies. At the same time, there is a recognition that these technologies are unlikely to be available for commercial use in the next 20 years and that the primary window of opportunity will fall somewhere between 20 and 50 years from now.

The level of knowledge about energy related issues is higher than was anticipated at the outset of this project and the attitude patterns are more positive and optimistic than had been expected. However, it is evident that there are gaps in the backgrounds and technical vocabularies of a number of the leaders. While there is strong optimism that future energy technologies will be clean and commercially cost-effective, it is clear that a substantial portion of these leaders do not understand the mechanics of the fusion process or the nature of complex technologies such as lasers. As research in these areas continues over the next decade or two, it is important that industry, environmental, and science policy leaders understand the level of achievement that has been obtained and the remaining questions that need exploration and demonstration.

The results of this survey would suggest that those who are involved in research laboratories have not adequately communicated with many of those who will participate in formulating the nation's future energy policies. For example, it would appear from these data that a significant portion of the leaders are at least a little foggy in regard to the differentiation between fission and fusion. It is therefore reasonable to expect that some of the difficulties experienced with fission-based systems to date may be generalized by some of these leaders in thinking about fusion technologies in the future. It is evident that, in communicating the basic scientific concepts and technologies to the policy leaders, efforts must be made to avoid confusion and to add clarity to subjects that are today not adequately understood.

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