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A Study of Energy R and D in the Private Sector

November 1979

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Prepared for:
U.S. Department of Energy
Assistant Secretary for Policy and Evaluation

Under Contract No. EX-77-C-01-6089

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St. Louis, Mo. 63105

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U.S. Department of Energy
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Washington, D.C. 20585

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A Study of Energy R and D in the Private Sector

November, 1979

Department of Energy (DOE) EX-77-C-01-6089

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Following is a list of the consultants who conducted the interviews and provided invaluable contribution to and assistance in the preparation of this report. All ten are Emeritus Members of the Industrial Research Institute.

H. L. Craig*	Retired 1973 from position as Director Product Development Division, Procter and Gamble
F. L. Cuthbert*	Retired 1973 from position as Associate Director Research and Development, NL Industries
E. M. Dannenburg	Retired 1974 from position as Vice President and Scientific Director, Cabot Corporation
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O. H. Johnson	Retired 1971 from position as Vice President and Director Research, Chemical Group, FMC Corporation.
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W. B. Reynolds	Retired 1970 from position as Vice President, Research and Engineering, General Mills, Inc.
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* Participated in both years.

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Administrative Assistance	Roselaine Carignan Janis Smith
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ABSTRACT

The purpose of this study is to supply the Department of Energy (DOE) with information pertinent to the formulation of realistic national energy research and development policies and to facilitate cooperation between government and business in the development and commercialization of new and improved energy technologies. The study gathered information on the amount of energy-related research and development (R & D) private companies are doing, the types of energy-related R & D they report, and their perceptions about appropriate areas for government support.

To obtain this information, the Industrial Research Institute Research Corporation (IRI/RC), in conjunction with Rensselaer Polytechnic Institute (RPI), used mail questionnaires and personal interviews to gather data over a two year period. Data collected in Year I (October 1977 - May 1978) were submitted to DOE in a self-contained report in September 1978.* This report focuses on Year II findings (October 1978 - May 1979).

The mail questionnares obtained data on the amount of corporate R & D funding in specific energy-related technology areas. In Year II, the questionnaires were sent to 814 companies chosen to represent a broad spectrum of American industry. These

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*"A Study of Energy R and D in the Private Sector: Phase Two", Industrial Research Institute Research Corporation, 7800 Bonhomme Avenue, St. Louis, Missouri 63105, September 1978.

companies account for a substantial amount of the nation's R & D. Three-hundred and fifty-one (351) companies returned questionnaires.

The interviews gathered information from top-level executives on overall corporate energy strategies and on specific energy-related R & D plans and projects. In addition, the executives described their perceptions of the role government plays in facilitating and/or inhibiting the commercialization of new technologies and identified areas of government support that would be helpful to their respective companies.

Eighty-seven on-site and eight telephone interviews were conducted. The ten consultants who conducted the interviews were Emeritus Members of the Industrial Research Institute and were formerly senior R & D executives before they retired.

In this and all preceding reports, all information, quantitative and qualitative, is aggregated in a manner sufficient to protect the confidentiality of individual participants.

Major Findings of Mail Survey

- The total corporate funded Energy R & D reported by 351 responding companies was approximately $823 million (1976)*, $945 million (1977), and $1.11 billion

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* If data from 61 Year I respondents who did not respond again in Year II is added to this figure, the reported amount of 1976 expenditures becomes $1.13 billion. In the main report, expenditures are reported for 102 technology areas.

(budgeted 1978). Based on this sample, the percent of R & D that was energy-related ranged from approximately 10% in 1976 to approximately 12% in 1978. If one restricts consideration to only those companies reporting Energy R & D, these percentages increase to approximately 15%.

- Extrapolation of the results of this survey indicate that for the three year period, privately-funded Energy R & D was approximately $2 billion annually. The rate of annual increase from 1976 to 1978 in privately-funded Energy R & D does not seem to significantly exceed the inflation rate during the period.

- Of the ten technology areas receiving the most Energy R & D corporate funding, six are associated with conservation. (Chemical and Refining Processes, Improved Energy Saving Processes, Electric: Transmission and Distribution, Electric: Environmental and Pollution Abatement, New Energy Saving Processes, and Aircraft Engine and Airframe) This represents 27% of the total itemized Energy R & D reported. Three supply-oriented technologies appear in the top ten list and are concerned with near to mid-term commercialization efforts. (Geological Assessment Techniques, Batteries, and Oil Drilling and Production Techniques.)

- When asked to comment on the degree of importance of various technology areas for receipt of DOE support, all aspects associated with nuclear R & D and coal gasification and liquefaction received very high ratings by a majority of respondents.

MAJOR INTERVIEW FINDINGS

Industry feels that it cannot shape long-range corporate energy strategies or undertake long-lead high-risk energy R & D ventures in the current climate of uncertainty.

Companies call for a rational and consistent national energy program which will reduce the number of conflicting and ever-shifting regulations to which they are subject. Furthermore, they urge that price controls, allocations, and mandated conversions be lifted to establish free market conditions which they believe are essential to solving our national energy problems. A comprehensive energy plan would also include programs for each energy source or technology including development goals.

Concern for an uninterrupted supply of energy has motivated many companies to assure their own sources of supply.

In the interest of assuring an uninterrupted supply of energy, consumer product companies have undertaken conservation efforts and developed various capabilities for producing in-house sources of energy. Companies who produce energy primarily for sale have also shown an interest in conservation and have undertaken exploratory projects to uncover more energy resources. These efforts, which primarily can bring only near and mid-term results, are an attempt to reduce corporate dependence on uncertain outside energy sources. These uncertainties are caused both by the political vagaries of foreign governments and by our own government's shifts in pricing, allocations, and conversion regulations.

Although conservation has been a main element of corporate energy strategy, industry now feels that conservation efforts have reached a point of diminishing returns.

Industry reports that the obvious conservation improvements have been made. Further progress will require greater and greater capital expenditure and correspondingly high risk. Future conservation projects will be evaluated in relation to other projects on the basis of their potential return on investment.

The vast majority of companies recommend the development of nuclear and coal technologies to increase our national production of electricity.

This opinion was expressed in both the mail questionnaires and personal interviews. By supporting and expanding nuclear power and coal combustion for stationary equipment, more petroleum fuels will be available for essential portable equipment and chemical feedstocks. The development of an electric/hybrid automobile and liquid synthetic fuels can further ease the burden on diminishing petroleum supplies.

There is general consensus that government should support basic research in universities, government laboratories, and in industrial R & D settings, and that it should not become involved in commercialization when industry has the capacity to do so.

Most companies agree that government support may be necessary for long-range technologies or where costs and risks are extremely high, for example in the development of nuclear power, oil resources, or rail transportation. However, a major opinion is that government can do more to stimulate industrial R & D by reducing the number of its regulations and by providing tax breaks and other incentives.

Although industry places emphasis on the importance of nuclear and coal technologies, it acknowledges that all forms of energy should be explored to help solve our energy problems.

When trying to stimulate the development of technology in renewable resources, e.g. in solar energy, industry recommends that DOE support basic research rather than attempt to commercialize an immature technology.

PROJECT GOALS AND OBJECTIVES

The purpose of this study is to supply the Department of Energy (DOE) with information pertinent to the formulation of realistic national energy research policies and to facilitate cooperation between government and business in the development and commercialization of new and improved energy technologies. The study gathered information on the amount of energy-related research and development (R & D) private companies are doing, the types of energy-related R & D they report, and their perceptions about appropriate areas for government support.

To obtain this information, the Industrial Research Institute Research Corporation (IRI/RC), in conjunction with Rensselaer Polytechnic Institute (RPI), used mail questionnaires and personal interviews to gather data over a two year period. The mail questionnaires obtained data on the amount of corporate R & D funding in specific energy-related technology areas. The interviews gathered information from top-level executives overall corporate energy strategies, major commerical activities, and specific R & D plans and projects in four major energy areas:

Conservation

Supply

Energy Production and Transmission

New Products

In addition, each company was asked to provide specific information on the policies and/or actions of fifteen government agencies that have facilitated or inhibited energy-related pursuits, as well as the degree of importance of each agency relating to the energy strategy of the company, and on its R & D programs in particular. Finally, the respondents were asked to indicate the degree of importance to their company for DOE support in thirteen specific areas of energy technology and were given an opportunity to express any wrap-up message regarding the energy situation that should be brought to the attention of DOE policy makers.

Data collected in Year I (October 1977-May 1978) were submitted to DOE in a self-contained report in September 1978.* The results presented below will focus on Year II findings (October 1978-May 1979). However, data on 1976 expenditures collected in Year I are incorporated into Year II findings.

The Year II component of this study differed primarily in magnitude: mail questionnaires were sent to 281 companies in Year I and to 814 companies in Year II; interviews were conducted with 47 companies in Year I and with 95 companies in Year II (8 of the latter via telephone).

Year I focused on companies known to be energy-intensive, while the Year II sample included more companies not necessarily known to be heavily engaged in Energy R & D. Over 50% of the Year I companies surveyed were IRI companies, many of whose

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* "A Study of Energy R and D in the Private Sector: Phase Two" Industrial Research Institute Research Corporation, 7800 Bonhomme Ave., St. Louis, Missouri 63105, Sept. 1978.

R & D managers were personally known to project staff. Thus, the project's access to Year I companies was somewhat greater than to Year II companies.

In addition to differences in the sample and in access to the sample, the format for the questionnaire and interview guide were somewhat modified based on Year I experiences. Among other things, these modifications allowed for greater detail of response.

Finally, it should be noted that the term R D & E (research, development, and engineering) rather than R & D was used throughout Year I. In Year II, a standard definition of R & D, which includes development engineering, was cited and briefly discussed in supplemental instructions accompanying all questionnaires. The use of these slightly different terms is not felt to have caused definitional difficulties.

Copies of the mail questionnaire, interview guide, and supplemental instructions for Years I and II are provided in Appendix A.

In this and all preceding reports and communications, all information, quantitative and qualitative, has been aggregated in a manner sufficient to maintain and protect the confidentiality of individual questionnaire respondents and interview participants. This dedication to confidentiality is a stated condition of this contract. Every participant in the project, and every questionnaire and interview respondent has been duly apprised. Positions, opinions, and perceptions in this report are based, to the best of the authors' abilities, upon the information provided by the corporate participants in the mail survey and interviews and do not necessarily reflect the position of DOE.

ANALYSIS OF MAIL SURVEY

SAMPLE DESCRIPTION

The Year II questionnaire was mailed to 814 U.S. corporations. These included: (1) all 624 companies listed in Business Week's* (BW) "Fourth Annual R & D Scoreboard;" (2) the domestic membership of IRI, about 240 companies, most of which were included in the BW list; (3) a stratified random sample of some smaller, high-technology companies (sales below $25 million) and closely regulated industries such as electric and gas utilities, trucking companies, and airlines. The BW R & D survey provided an excellent basis for the mail survey because the cumulative R & D performed by the listed companies represents the vast majority of the nation's R & D. Furthermore, it provided the project team with an extensive source of information upon which to base later extrapolations and comparisons.

The table below indicates the number of companies who responded and whether or not they supplied quantitative data.

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* Business Week, July 3, 1978.

	Number	%
Companies responding with quantitative data	271	33.3
Companies responding but indicating no Energy R & D	80	9.8
Companies indicating they would not participate	80	9.8
Companies not responding	383	47.1
TOTAL	814	100

Approximately 43% (N=351) of the 814 corporations returned questionnaires. This response rate is slightly less than the 50% response rate in Year I. As noted earlier in this report, over half the Year I company representatives were personally known by project staff, which probably increased company willingness to participate. Furthermore, many, if not most, companies are understandably reluctant to participate in surveys. They are beseiged with requests for information, which require considerable time and effort.

Because the project staff anticipated these difficulties, an intensive effort was made to elicit responses. The first mailing was by certified mail, return receipt requested. Virtually all receipts were received. Each packet contained a personalized cover letter, a copy of the questionnaire with supplementary instructions, a copy of the Year I summary report, a postcard for recipients to return indicating if and by when they would respond. The approximately 134 companies who were also in the interview sample were contacted by their assigned interviewers who added their own personal letter of introduction and indicated there would be a follow-up telephone conversation to arrange a personal interview. If companies did not return the postcard, they received follow-up mailings at approximately six week intervals, with the last mailing sent in late January 1979. Personalized reminders were mailed to firms whose stated response date was overdue.

In reviewing the Year II mail survey results, it is important to note that 23% of those companies returning questionnaires indicated that they performed no Energy R & D. It is also important to note that the major automobile manufacturers are seriously underrepresented. In both Years I and II, they maintained a non-response policy to mail questionnares.

MAJOR FINDINGS

Spending Characteristics of Responding Companies

The table below summarizes the totals listed on the front page of the questionnaire responses for corporate sales, corporate funded R & D, and other funded Energy R & D for 1976, 1977 and 1978. As the table indicates, the total corporate funded Energy R & D reported by the 351 companies responding in Year II was approximately 823 million (1976),* 945 million (1977), and $1.11 billion (budgeted 1978).

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* If data from 61 Year I respondents who did not respond again in Year II are added to the data from the 351 Year II responding companies, the reported amount for 1976 expenditures becomes $1.13 billion.

FRONT PAGE SUMMARY FOR THE 351
COMPANIES RESPONDING TO THE YEAR II SURVEY
(dollars in millions)

	1976	No.	1977	No.	1978**	No.
TOTAL CORPORATE SALES	441,548	332	500,065	340	507,663	299
TOTAL CORPORATE FUNDED R AND D	8,056	314	8,412	312	9,442	293
CORPORATE FUNDED ENERGY R AND D	823	167	945	175	1,115	177
FEDERAL FUNDED ENERGY R AND D	280	49	361	60	434	69
OTHER FUNDED ENERGY R AND D	16	15	108	28	111	28

The following table indicates the percent of Total R & D to Total Sales and Total Energy R & D to Total R & D for 1976 and 1977 actual corporate expenditures and for 1978 budgeted expenditures. Figures are presented for all 351 responding companies and for only those companies performing Energy R & D.

	R&D/Sales			Energy R&D/Total R&D		
	1976	1977	1978	1976	1977	1978
All Companies	1.8%	1.7%	1.9%	10.2%	11.2%	11.7%
Energy R&D Performing Companies	1.6%	1.7%	1.7%	15.5%	15.0%	15.5%

These ratios have been used to obtain estimates for the approximate total Energy R & D being privately funded in the nation. This is difficult inasmuch as no one really knows the total privately funded R & D performed. However, the R & D

** 1978 Figures are for budgeted expenditures.

listed in the BW annual surveys probably represents about 90% of the nation's private expenditure for R & D.

In order to extrapolate to a wider population, one must assume that Energy R & D expenditures are in the same proportions in both the responding and wider populations. Project staff calculated the ratio of Energy R & D to Total R & D of the 263 BW companies who returned questionnaires. It was determined that the responding BW companies were spending approximately 9.5% of their Total R & D budget on energy-related activities. This ratio was then applied to the total R & D for all 624 BW companies in the BW survey, <u>except</u> for the automobile industries.

As mentioned earlier, some of the BW companies included automobile manufacturers who were seriously underrepresented in the response population. Since it is assumed that the automobile industry probably spends more on Energy R & D than the average spent by other BW companies, different, and presumably more accurate, ratios were used to calculate their spending: the ratios used were those derived for all responding BW companies who claimed any energy R & D spending: 11.2% in 1977 and 11.7% in 1978.

In addition, project staff added on the amount reported by the 88 non-BW respondents. Thus, the estimates of Energy R & D expenditures for 1977 and 1978 which appear below are based on estimated spending for 712 companies - 624 in the BW surveys for those years and 88 non-BW respondents.

Because information was gathered both from Year II respondents and from an additional 61 respondents in Year I who did not respond again but for whom data exists, it is also possible to revise and refine the estimate given for 1976 expenditures in the Year I report. The extrapolated estimate below for 1976 Energy R & D spending is for 728 companies, 528 companies in the BW 1976 "R & D Scoreboard" and the 130 non-BW respondents for that year.

<u>Estimated Total National Corporate Energy R & D</u>

1976	$1.9 billion
1977	$2.0 billion
1978 (Budgeted)	$2.4 billion

It must be emphasized that these estimates are based on a relatively small number of responses and they cannot be considered to be precise. It does seem reasonable to conclude, however, that (1) over the three year period, 1976 through 1978, the private expenditure on Energy R & D was of the order of, and probably somewhat greater than, $2 billion per year, and (2) over this period, while a positive trend in spending is discernable, the rate of increase does not significantly exceed the inflation rate.

Year I findings estimate that total national 1976 Energy R & D expenditures were between $2.0 and 2.3 billion. The slightly lower Year II estimate of $1.9 billion has been revised to take advantage of the larger sample size. The higher Year I 1976 estimate also resulted from inclusion of one company's Total R & D figure in the Energy R & D sum, because they had purported that all their R & D was energy-related. Since this claim later proved to be exaggerated, the figure (a substantial amount) was withdrawn from the revised Year II estimates.

It is also important to note that the Year II estimates for 1977 and 1978 may be somewhat underestimated. One contributing factor is that some Year I respondents failed to respond to the questionnaire in Year II. Some of these corporations were very large, R & D intensive, organizations. Furthermore, there were some indications that in Year I companies doing Energy R & D were more likely to respond than companies doing no Energy R & D. Year II supplemental instructions pointed out that even information reporting that a company did no Energy R & D would be useful. Thus, Year II if a company did no Energy R & D, it became easier to respond, while it was far more difficult and time-consuming for companies that did do R & D to respond.

Rank-ordered Importance of Energy Technology Categories

In addition to total corporate spending on Energy R & D, the questionnaire sought information on spending in 13 broad energy categories. These appear below in order of the corporate spending they were reported to have received.

RANKING ENERGY CATEGORIES BY 1978 DOLLAR SPENDING R & D

	Rank	$Millions
(1) Oil	1	195.1
(2) Manufacturing/Process Changes	2	166.3
(3) Electric Power Generation	3	138.6
(4) Transportation	4	99.7
(5) Nuclear	5	92.7
(6) Coal	6	68.0
(7) Miscellaneous	7	62.7
(8) Energy Storage	8	45.1
(9) End Product Efficiency	9	34.6
(10) Air Conditioning, Heat Pumps & Heat Recovery	10	34.3
(11) Solar and Other Renewables	11	32.4
(12) Gas	12	29.4
(13) Industrial Combustion & Steam Generation	13	16.9
TOTAL FOR ALL CATEGORIES		1,015.8

The Top Ten Technology Areas

The thirteen categories were further subdivided into 73 more specific technology areas. Respondents were asked to indicate corporate spending for each area. Also, within each category, space was provided for respondents to specify other technologies in which they were doing Energy R & D. Based on these additional entries, 29 new technology headings were created, for a total of 102 technology areas. Naturally, some guessing had to be done and some arbitrariness introduced to organize the new entries, but the result is felt to be more informative about where the Energy R & D dollar is being spent than if the amounts reported for these additional technologies were simply cumulated and exhibited under an "Other" label. The following table lists the ten technology areas with greatest reported amounts for 1978, listed in order of decreasing magnitude.

	Technology Area	Total Energy R & D (Millions)	No. of Respondents	Rank in 1977	Rank in 1978
(1)	Chemical & Refining Processes	61.2	59	1	1
(2)	Improved Energy Saving Processes	48.5	110	4	4
(3)	Electric: Transmission & Distribution	48.1	20	2	5
(4)	Electric: Environmental, Pollution Abatement	46.5	10	3	14

(5) Geological Assessment	42.3	14	5	2
(6) Batteries	38.6	16	6	18
(7) New Energy Saving Processes	36.5	94	7	7
(8) Aircraft Engine & Airframe	30.4	15	11	8
(9) Oil Drilling & Production Techniques	28.4	9	10	12
(10) Light Water Reactors	26.0	7	9	15
TOTAL	406.5			

Consistent with Year I findings, this table indicates an apparent priority on conservation technologies. Six of the top ten areas, viz. numbers 1,2,3,4,7 and 8, are associated with conservation. They represent 271 million dollars or 27% of the total itemized Energy R & D reported. The energy supply-oriented technologies that appear in the top ten, viz. geological assessment techniques (5), batteries (6), and oil drilling and production techniques (9) are techniques that can be expected to bring results in near to mid-term commercialization efforts. These three represent 109 million dollars or 11% of the total itemized Energy R & D reported.

Tables provided in Appendix B present information on corporate spending in each of the 102 technology areas. Table 1 summarizes 1976, 1977 and 1978 reported spending in each of the 102 technology areas in addition to spending labeled "other" for responses that resisted grouping. Tables 2, 3, and 4 group the response magnitude of spending categories, (viz., no amount reported, less than $100,000, $100,000 to $500,000, etc.) for 1976, 1977 and 1978 respectively. This may serve to indicate the size of individual projects that companies are working on, although this presentation can do so only in a gross manner.

Comparative Spending Among Industrial Sectors

Various analyses have been performed that provide information on comparative rates of Energy R & D spending among different kinds of industries. This information is presented in Appendix C. Tables 5 - 7 in Appendix C list the totals for R & D and Energy R & D as well as the ratios of R & D to Sales and Energy R & D to Total R & D for 37 industry sectors for 1976, 1977 and 1978, respectively. Data from sectors in which the number of responses were very small were deleted to preserve confidentiality. However, these data remain in the totals. For more convenient comparison across years, Table 8 presents the ratios of R & D to Sales and Energy R & D to Total R & D for the 37 sectors for 1976 through 1978. Tables 5 - 8 report on all companies, including those reporting zero Energy R & D.

However, a substantial number of the responding companies report that they perform no Energy R & D. Other companies indicated (by checking appropriate boxes in the inventory on the inside of the questionnaire) that they were involved in Energy R & D, but then did not report actual expenditures. Tables 9 - 12 in Appendix C present the same kinds of information shown in Tables 5 - 8, but figures are presented only for those companies reporting Energy R & D expenditures.

Since many of the 37 industrial sectors are represented by only a few companies, they were combined into 10 major groups, according to a mapping displayed in Table 13. R & D and Energy R & D, as well as the ratios of R & D to Sales and Energy R & D to Total R & D, for these 10 major groups are listed in Tables 14 and 15 for all companies, including those reporting zero Energy R & D. Table 16 presents the same kinds of information, but only for those groups reporting some Energy R & D.

The information below summarizes the comparative rates of Energy R & D spending among the 10 major industrial groups. (Only companies reporting some Energy R & D are included here.) Examination of these figures indicates dramatic variation in the percentage of Energy R & D spending among the ten groups. However, it is difficult to draw conclusions about these variations because there is also great variation within sectors. Therefore, the estimates should not be thought of as estimates of what a "typical" company within a sector is doing, but rather as an estimate of what the sector as a whole is doing.

COMPARISON BY YEAR OF R & D PERCENTAGES OF
10 INDUSTRIAL GROUPS

(COMPANIES REPORTING ENERGY R & D)

SECTOR	1976 R&D/ SALES	1976 ENERGY/ TOTAL R&D	1977 R&D/ SALES	1977 ENERGY/ TOTAL R&D	1978 R&D/ SALES	1978 ENERGY/ TOTAL R&D
High Technology Companies	6.7%	3.1%	6.4%	2.9%	6.8%	3.2%
Chemicals	2.8%	9.0%	2.8%	7.0%	2.8%	8.0%
Coal, Oil & Gas	.5%	51.6%	.5%	50.5%	.5%	54.3%
Consumer Goods	1.5%	5.2%	.7%	9.8%	.8%	10.7%
General Machinery	1.4%	28.5%	1.2%	32.5%	1.2%	33.3%
Electrical Equipment	2.4%	21.1%	2.3%	23.9%	2.5%	23.0%
Light Industry	2.8%	9.6%	2.8%	10.3%	2.8%	11.2%
Miscellaneous Companies	1.0%	10.1%	2.0%	5.8%	2.0%	6.4%
Electric Power	.7%	91.4%	.7%	96.5%	.7%	97.4%
Bldg. Mat'ls, Metals & Mining	.9%	10.4%	.9%	13.5%	.9%	10.9%
Totals	1.6%	15.5%	1.7%	15.0%	1.7%	15.5%

Rank-ordered List of Technology Areas Recommended for DOE Support

Companies were asked to indicate the degree of importance they thought DOE should give to each of the 73 technology areas listed in the mail questionnaire. The following is the list of technology areas rated very important for receipt of DOE support by the companies reporting at least some Energy R & D spending.

Electric Power Generation

Gas Turbine Combined Cycle

Fuel Cells

Fluidized Beds

Magnetohydrodynamic Generation

Industrial Combustion & Steam Generation

Waste Material

Energy Storage

Batteries

Thermal Energy Storage

Coal

Gasification

Liquefaction

Nuclear

Liquid Metal Fast Breeder

Waste Disposal

Reprocessing

Fusion

Fuel Separation

Fuel Production

Light Water Reactors

Other Fission

Solar & Other Renewables

Solar Photovoltaic

Biomass

When the data are analyzed, two features stand out. (1) All companies, not just those doing R & D in the area, came out very strongly in favor of heavy emphasis by DOE for R & D in practically all the technologies enumerated in the nuclear category. (2) With the exception of coal liquefaction and coal gasification, all companies, including those doing R & D in the coal, oil and gas categories, did not emphasize the need for DOE support in the coal, oil and gas categories. This observation tends to support the perception generated by the personal interviews that the energy supply cmpanies would prefer to "go it alone", with economic incentives other than direct DOE support to stimulate high risk, capital intensive R & D.

Appendix D provides more detailed information on the relative amount of DOE support companies recommend for each of the technology areas. As discussed above, each was asked to indicate the degree of importance that it thought DOE should give in its support of each technology. Responses allowed were: should not support (NS), not important(NI), important (I), amd very important, (VI). An index was constructed using a scale of 0 to 1000 by scoring the above categories 0, 400, 700 and 1000, respectively, and averaging over the response. The higher the index for a tech nology the higher the perceived worthiness for DOE support. While the scoring is somewhat arbitrary, the results are useful for comparing industry perceptions regarding the importance of the different technologies. In Table 17, these indices are exhibited for

(i) all companies responding

(ii) those companies responding and doing R & D in the energy category

(iii) those companies responding and doing R & D in the particular energy technology listed.

In Tables 18, 19 and 20, the percentages in the four response categories, NS, NI, I, NI, are presented. The percentages in the four response categories for the 10 major industrial groups are given in Tables 21A-21C.

Recommendations for Government Sponsorship of Energy R & D

In the personal interviews in Year I, the comment was made on several occasions that DOE should confine its support for universities and the national laboratories (public sector) to basic and some applied research whereas support for process engineering, pilot and demonstration plants should be allocated to those companies in the private sector possessing the potential for ultimate commercialization. Hence, a question requesting the opinion of each company regarding the current level of government sponsorship in these types of energy-related research was incorporated into the Year II mail questionnaire. For the 192 responses to this question, the distribution of responses over these types of research categories was essentially the same for the private sector and the public sector. This similarity persisted when the results were disaggregated according to company size. Although these responses tend not to support the Year I impression, it should be noted that the companies interviewed in Year I did not form a significant component of the Year II respondents to this question. Table 22 in Appendix D presents more detailed information on this question.

ANALYSIS OF INTERVIEWS

DESCRIPTION OF SAMPLE AND INTERVIEW PROCEDURE

Eighty-seven on-site and eight telephone interviews were completed in Year II. The following table indicates the kinds of companies interviewed:

High Technology Companies	12
Chemical Companies	8
Coal, Oil and Gas Companies	12
Consumer Product Companies	8
Basic Industries	16
Electric Companies	8
Light Industries	11
Miscellaneous Companies	12
TOTAL	87

For the most part, interviews were conducted with top-level corporate officers or executives in engineering R & D or planning, including, in some instances, company presidents and general managers.

Each interview was conducted by one of ten IRI Emeritus Member consultants, seven who had conducted the Year I interviews and three additional interviewers. These individuals were, themselves, ex-corporate executives and so were able to gain access to company representatives who otherwise might not have participated or who might not have been as frank with other interviewers.

The interviews were guided by a format which included the general points described below but were otherwise non-directive. They were from one to five and one half hours in duration. A separate report was prepared and submitted for each interview and these reports provided the basis for the summary to follow.

INTERVIEW OBJECTIVES

The main objective of the interviews was to obtain detailed descriptions from top corporate executives on several aspects of corporate energy strategy and its R & D component. Another major objective was to determine the impact of the policies, programs, regulatory activity, and other actions of DOE and other government agencies on corporate energy strategy and the commercialization of new energy technologies. Specific examples of how these actions have inhibited, facilitated, or otherwise affected the commercialization process were sought. Finally, interviewees were asked to indicate the relative importance to their company of DOE support of various energy technology areas. Aggregated interview responses for all these issues are presented in the remainder of this report.

It should also be noted that all the interviews were conducted before the incident at Three Mile Island. Currectly, there is no way of knowing if or how that occurence might have changed business commitment to nuclear energy. All the interviews were also conducted before phased decontrol of oil prices was announced.

For a description of industry's reactions to the National Energy Act, see pages 85-89 of this report.

CORPORATE ENERGY STRATEGY AND ITS R & D COMPONENT

Interviewees were asked to discuss their corporate energy strategy and its R & D component with respect to four categories: conservation, supply, energy production and transmission and new products. They were asked to describe their major concerns, plans, and projects in each area and to rate each category's importance on overall corporate energy strategy in the near, mid, and long-term.

An analysis of the corporate responses indicates that very little attention is being paid to long-term (beyond year 2000) activities. Industry feels that it cannot shape its own corporate energy strategy or undertake long-lead high-risk energy R & D ventures in the current climate of uncertainty. Companies call for a rational and consistent national energy program which will reduce the number of conflicting and ever-shifting regulations to which they are subject. Furthermore, they urge that price controls, allocations, and mandated conversions be lifted to establish free market conditions which they believe are essential to solving our national energy problems.

Three of the four issues addressed in this section, i.e., conservation, supply, and energy production, are closely interrelated components of corporate energy strategy and energy-related R & D. Corporate activities in these areas are motivated by an interest in minimizing energy dependence on uncertain outside energy sources--uncertainties that are caused both by the political vagaries of foreign governments and by our own government's shifts in pricing, allocations, and conversion regulations. In the interest of assuring an uninterrupted supply of energy, consumer product companies have undertaken conservation efforts and developed various capabilities for producing in-house sources of energy. Companies who produce energy primarily for sale have also shown an interest in conservation and have undertaken exploratory projects to uncover more energy resources.

Finally, as in all business ventures, companies approach possible R & D activities in these three areas with concern about the expected return on investment.

A discussion of the aggregated interview responses for all four categories appears below.

ENERGY CONSERVATION

Conservation is a main element of corporate energy strategies

Most companies consider energy conservation an important component of their overall corporate energy strategy. The economic motivations for these efforts are apparent: increasing pressures to keep their product costs competitive and a strong conern for the availability and uninterrupted supply of energy. For other industries, whose products or processes are not energy intensive, conservation is simply considered good management practice. A wide range of projects designed to reduce energy consumption have been implemented.

These projects range from small scale efforts, such as computerized car and van pooling programs to medium scale projects, involving known engineering principles and technology. More sophisticated innovative process changes requiring major capital expenditures and R & D have also been undertaken. These programs are expected to continue producing energy savings year after year.

Although, as will be discussed below, there is a widespread belief that a diminishing returns phenomenon has begun for additional major conservation efforts in the industrial sector, conservation apparently represents the principal component of corporate energy strategy. This is further corroborated by data collected in Years I and II mail surveys which indicate that private sector R & D expenditures in energy conservation comprise about 25% of all energy related R & D investment.

Typically these efforts have resulted in reducing total energy consumption by 15-30%. Several companies cited outstanding examples of the results of energy conservation programs:

--We consumed 31% less energy in 1977 than in 1976, yet we manufactured 41% more products.

--Using the base period of 1973, we are saving 3 trillion BTU's per year. (Approximate equivalent: 516,000 bbl/year of oil)*

--One plant originally designed for 150 tons of (product) per day was increased to 400 tons per day with only minor changes and no increase in fuel consumption.

--Using foreign-made trucks, we now get 20 MPG versus the former 10 MPG.

--We've had tremendous savings at our electric plant. By increasing the generator load at night the efficiency increases substantially. For example, at 60% of capacity on base load the efficiency is 32% as compared to 37% efficiency for operation at 85% of capacity.

--Result in energy conservation: from 25%-35% thermal efficiency in open cycle brought up to 70%-75% in the combined cycle.

--Since 1975 an 80% saving in natural gas use in our manufacturing process has been achieved by changing to by-product fuel.

Based on these and many similar examples reported, it is evident that industry has been, for reasons ranging from return maximization to stewardship, conscientious regarding in-house energy conservation and has indeed achieved some dramatic results in the reduction of energy consumption, especially with regard to industrial processes.

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* Based on an Institute of Gas Technology conversion factor.

Conservation projects will be evaluated in terms of return on investment.

Although many conservation efforts have been successfully implemented, there is a widespread belief that further conservation efforts will be decreasingly cost beneficial. Future conservation projects will be evaluated in relation to other projects on the basis of their potential return on investment. The obvious things have been done. While many were highly cost-beneficial some were done despite comparatively low return on investment because they were relatively risk free, represented good management, or displayed responsible "citizenship". Further progress, however, will require greater and greater capital expenditure and correspondingly high risk. Consequently, acceptable return on investment must not only be expected, but it also must be predictable within the reasonably narrow range necessary for prudent, long-range business management. In the present climate of extreme instability of government actions and practices, however, such prediction is difficult, if not impossible. Thus, most of the companies express a general reluctance to embark on major new programs involving large capital expenditures and significant process redesign, even though they may have very successful completed projects or very promising projects nearing completion. Some examples:

--Most of the housekeeping conservation measures have already been completed. The remainder are extremely capital intensive.

--Our extensive energy conservation program has produced results to the point where it is now difficult to find new challenges. Further savings in energy can be found, but they must show a pay-back and will have to compete with other projects.

--We get very conflicting stories from the government and from industry as to reserves. We could change our strategy if we had a prediction that we could accept.

--More effort will be required to achieve additional conservation savings beyond the substantial results achieved thus far.

--The next step in energy conservation includes major redesign of existing processes.

--We expect to justify energy savings capital expenditures using the same criteria that are used for all of our capital expenditures.

--The costs of government mandated conversion of paper operations from gas to coal make ROI very unattractive for up to 10 years.

--We have made steady progress in reducing energy consumption but now are reaching the limit of our possibilities.

--We have little room for improvement. Our older units are 97% efficient. Newer ones are less efficient due to environmental requirements.

--The mining of leaner ore deposits will result in increased energy consumption. There are no obvious areas for further important energy conservation measures with present processes.

--We know no way to reduce energy requirements for the manufacturer of polyethylene, which is extremely energy intensive. Attempted process changes have produced unacceptable products.

Although not often expressed, there is a contrast to the "easy things have been done" outlook that may be of some importance. Specifically, companies whose products are energy-conservation oriented and intended for industrial usage, (e.g. waste heat recovery systems, more efficient machinery of new, unfamiliar design) typically express the opinion that there are still cost beneficial conservation measures available for immediate application. Not many such companies were interviewed and consequently the validity of the concept is not possible to establish. These companies claim that their most difficult marketing problem is the reluctance of plant managers to accept these unproven systems for fear of production line interruptions. These fears allegedly arise from a perception that this equipment, although perhaps more efficient, may have lower reliability and maintainability. One company suggested that the government remove some of this risk by applying suitable economic incentives so that these energy efficient products could be proven and utilized throughout industry.

Other companies indicate that anticipated price increases in the near and mid-term will eventually enhance rate of return on conservation efforts made now.

> --We will expend capital for energy saving projects with longer return periods than for other, non-energy oriented projects. Return periods should shorten as time passses.

Although the exception to the rule, some companies remain willing to undertake conservation projects which promise low return on investment because such projects represent "good management" or "responsible citizenship" in some sense.

> --We consider conservation to be a matter of good management.

> --We are willing to allocate capital for energy savings

with a lower ROI than for other projects.

--We will accept a slightly poorer ROI on energy conservation projects than normal.

--Energy conservation projects do not have to conform to normal financial criteria.

--We make interest-free loans to our operating units to finance conservation programs.

<u>Conservation efforts were often undertaken to ensure the availability of an uninterrupted supply of energy.</u>

Many energy intensive and non-intensive companies state that, at least in part, their conservation strategies seek to reduce uncertainty of supply. In fact, when availability and uninterrupted supply of energy or of a particular type of energy (e.g. natural gas for direct drying) is crucial to a company's operations, cost of energy and return-on-investment may not be the most important investment decision criteria. Thus for many companies, uncertainty of supply quantity, source, or price is an incentive, albeit a negative one, to invest capital in energy conservation, even when such expenditures are not extremely justified on a return-on-investment basis.

--All of our product lines are highly competitive. The company cannot exist without an adequate supply of energy at reasonable cost. Continuity of supply is critical to all our operations.

This concern for an uninterrupted supply of energy was often central to the discussion of corporate energy strategies and is discussed in greater detail in the next section on Supply.

Companies find that the lack of a national energy policy and the unpredictability of the policies of various government agencies make future conservation plans less attractive.

Companies complain that federal agencies hamper their conservation efforts by implementing inconsistent policies, forcing change by regulation rather than by incentives such as tax credits, by banning full cost accounting, and in general by forming short range policies rather than working toward long range national energy goals. Several companies made strong suggestions for improving the relationship between government and industry. These include:

--DOE should take the lead in resolving inter-agency conflicts so it could help industries. Some positive moves could include funding for chemical recovery from paper mills, preferably through a consortium, funding or other incentives for burning wood, and allowing free market pricing to be the incentive for conservation rather than regulations, since industry and the population will effect conservation when pricing provides the incentive. Over-emphasis (on prior achievements in conservation) leads to a sense of false security of possible accomplishment.

--The government should make greater efforts to provide incentives for further conservation measures. Some significant capital expenditures that would have saved a great deal of energy have had an unacceptable ROI due to government monetary policies.

--The actions of the regulatory agencies should be more realistic and well thought out as regards pricing and control of consumption rates to the customer. Such policy changes would make conservation programs more promising.

--Methyl Managanese Tricarbonyl (gasoline anti-knock additive outlawed by EPA) should be reevaluated in terms of a cost benefit ratio. It represents a possible saving of 35-70 million barrels of crude per year. The use of leaded gas need not be discouraged in all areas of the country, since it is a hazard only in some areas.

Several companies made a strong plea for removing emphasis on increasing the miles per gallon of gasoline for automobiles. Their general rationale for this is that it is less expensive for them to build automobiles that run on synthetic fuels than it is to continue improving gas mileage. One comprehensive statement demonstrates this point:

> --There is a need to resolve inter-government agency conflicts related to energy production. The government is ignoring technology already available which would insure our domestic energy supply, independent of imports. The investment cost of oil saved by the end of the 1980's by redesigning the auto will be at the rate of $40,000-$50,000 per barrel per day of oil saved. This may turn out to be twice the cost of investment to generate this same liquid energy from solids. It is foolish to push the efficiency of the automobile to a cost where the customers can not afford to buy the car. In the present program there is a self-destruct element which eventually will be either changed by Congress or blamed on industry and OPEC.

SUPPLY

Concern for an uninterrupted supply of energy has motivated many companies to assure their own sources of supply.

An uninterrupted supply of energy is crucial to most business operations. In fact, the need to assure continuity of energy is no longer motivated by economics alone, but has actually become a mater of survival in many cases. This concern has caused many cmpanies to drill for their own oil and gas or open their own coal mines. Other activities to assure continuity of energy supply include the economic use of coal to replace oil and gas when possible, the use of byproducts as alternate fuel sources, cogeneration, the production of gas from biomass, and the installation of equipment to burn alternate fuels and store LPG and coal. These activities include both on-going programs and substantial R & D efforts. Energy producing companies have increased expenditures covering R & D programs and commercial developments related to increased crude oil production through primary, secondary, and tertiary (EOR) techniques, as well as R & D programs for the development of synthetic fuels from shale and coal.

At least eight companies report successful projects or planned R & D efforts for the use of wastes as fuel sources:

--One of our new plants will obtain 100% of the fuel for its boilers from waste products. Over 30% of the total energy used by the company (including gas, oil, coal, electricity, and waste materials) is now generated from waste materials. Of our total purchased fuels, waste materials represent over 50% of our energy as compared with our other purchased fuels.

--For the mid-term, we may have to consider the use of in-house scrap. However, we would have to supplement this with other sources of scrap to make it a large enough project to be worth the money.

--We have an energy-from-trash project, applying our experience with large boilers. We expect the program to grow in the near term.

--We are starting to pay some attention to the incineration of combustible plant wastes as a source of energy.

--We are burning waste oil as burner fuel.

--We use municipal refuse as fuel. Also, we have increased our use of wood as a replacement for fossil fuels.

Most R & D efforts to develop alternate fuels concentrate on technologies that can promise near or mid-term commercialization. The following statements refer to near-term efforts:

--We are paying attention to the nature of the optimum supply source in terms of its ultimate use -- e.g., boiler fuel in the refinery, fuel for customers, feedstocks for petro-chemicals, etc.

--Though our major plant fuel is natural gas, we have developed standby provisions to switch from gas to propane or oil as alternate fuels.

--By edict of top management, we are paying attention to the use of alternate fuels on a cost-feasible analysis.

--Our project with DOE involves an improved catalyst for coal liquefaction.

--We have increased our use of wood to replace fossil fuels.

--We are looking at other sources of chemical feedstocks, not at liquefaction or gasification.

--We are doing R & D on glycol manufacture using syngas.

--Our R & D is aimed at more efficient fuel use. Alternate fuels begin to compete with gasoline at about $2.00/gallon. We have studied all kinds of fuels -- gasohol, synthetics, even hydrogen.

--We have invested in equipment to burn and store alternate fuels (oil, gas, and maybe coal) and to store emergency fuels. Some processes cannot use alternate fuels like metal and heat treatment and furnace brazing.

Mid-term efforts include:

--A possible project for the mid-term is fuel plantations, e.g., faster growing forests specifically for fuel use rather than for paper stock.

--We do R & D on liquid fuels and gas from wood.

--We will move to alternate fuels as mandated or dictated by economics.

--For the mid-term, we believe we will make greater use of biomass and will have to use all sources, i.e., nuclear, etc., "even solar".

--For the long-term, we expect our concern to become more important, but we cannot specify in what way.

Discussion of long-term efforts appears more general and speculative:

--Calorific Recovery Anaerobic Process (CRAP) and coal gasification, and biomass will be important for the long-term.

--For the long-term, solar may provide a small percentage of our electric power, perhaps comparable to nuclear's present contribution.

--Some alternate form will be available. It is even possible that it will be so cheap and available that it might be free.

The vast majority of companies recommend development of nuclear and coal technologies to increase our national production of electricity and for other vital industrial processes.

The following statements demonstrate corporate interest in nuclear and coal technologies for increasing production of electricity:

--For mid-term, we plan on using more electricity. We feel the country should be building more coal and nuclear electric generating units. It takes ten years to build these units, so we should be moving very aggressively to build these units right now[

--For the long-term, we need electricity through nuclear fusion.

--We believe the future should lie in the use of coal with fluidized bed equipment (to provide electricity and steam) and that we should not try to convert to liquids first. Obviously, this is for stationary equipment.

--The country should be and is moving toward an electric economy to bridge the gap between petroleum and synthetic liquid fuels. Nuclear energy is absolutely essential to bridge that gap.

--Oil and gas from coal and shale will be defeated by poor economics. Solar will not be important. The government must solve the nuclear regulatory bottleneck so we can have lower cost electricity.

--Utilities are 75% coal based. We see no growth in nuclear, and the availability of liquids and gases is declining and their costs are increasing. Biomass will not have a significant impact, despite our location in a heavily forested area.

By supporting and expanding nuclear power and coal combustion for stationary equipment, more petroleum fuels will be available for essential portable equipment and chemical feedstocks. The development of an electric/hybrid automobile and liquid synthetic fuels can further ease the burden of diminishing petroleum supplies. These points are discussed in more detail later in this section.

Coal is also vital to many other industrial processes:

--Our major source of fuel is coal, with 25-30% coming from captive mining operations and the rest from outside. We need continued supplies from outside. We do some of our own work on sulfur removal and other preparation of coal.

--65-70% of our energy comes from coal. We are concerned whether we can move it, get the quality coal we require to make coke, and find new coke making processes.

--We are assuming gas will not be available in the future and we will therefore have to use coal, either directly or indirectly. Because of possible carcinogenic contributions of some fuels, we will have to use steam for evaporation or indirect drying.

Though conversion will be time-consuming and expensive, coal is thought of as a possible replacement for gas and oil by those companies which can use it without decreasing the quality of their product:

--For the long-term, we expect to switch to coal as our major source of energy. This entails major redesigns of processes and facilities.

<u>Oil and natural gas will continue to be necessary energy sources for certain industries for a long time.</u>

Even with a strong thrust toward alternate supplies of energy including nuclear, solar and biomass, certain industries will require natural or synthetic oil and natural gas for a long time. This is especially true for companies critically dependent upon the special combustion properties of natural gas and for companies facing large and complex conversion problems. For example:

--More than 20 years will be required to develop, check and set up a distribution system for a new fuel for planes. Therefore, kerosene will be necessary for 20 years at least. We expect the demand for turbine fuel to grow twice as fast as the demand for other fuels in the period 1980-1990 (i.e., 3% per year vs. 1 1/2% per year). We expect the critical period for shortages will be in the next 10-12 years.

--We must have energy in a form compatible with food processing. We need clean fuels such as electricity, natural gas and LPG. Direct heating for food product drying is about 70% efficient, while indirect is only 30-40%.

Other companies depend on natural gas for heat treating, curing coatings, and glass operations. These processes are not considered economically amenable to the utilization of coal or oil. As the following statements indicate, many companies rely upon natural gas as a major fuel:

--Natural gas is a major fuel. The supply of natural gas is basic to our profits. Two years ago some plants were shut down because of the gas shortage. It was necessary to buy expensive propane with a major impact on operations, expense, and profits.

--In the 1977 gas crisis, the closing of one plant cost us $2 MM.

--Our major plant fuel is natural gas. Our operations could be seriously hurt if gas supplies become unavailable or substantially reduced.

--We are concerned about conflicting public statements regarding the available underground supplies of natural gas.

--We will use gas as long as possible. We think it will be available for 5-10 years. We should have priority for gas under the New Energy Act, since we are manufacturing agricultural products where there is direct contact between the combustion gases and the food product.

--A continuing source of gas is critical. We sold all our wells 14 years ago since we expected federal regulations would prohibit the transmission companies from owning wells.

Eleven companies state that oil and gas are their primary energy sources. While one or two companies say they feel supplies will be adequate, most companies express concern:

--Oil and natural gas availability and continuing uncertainty are concerns.

--Oil is a key factor in our fuel supply source. Natural gas is, too. Coal has to be considered. Uncertainty of the supply and cost of oil is a grave concern.

--We have converted boilers to burn gas or oil. Large storage tanks for oil have been installed at our largest unit to avoid interruptions in supply. We assume gas or oil will be available. We have no plans to move to coal, because rapid changes in steam loads do not lend themselves to coal fired boilers.

--Our primary sources of energy are gas and oil. We use some electricity for heat treating.

--All our plants will be converted to burn gas and oil (now they burn primarily gas). Some of the plants are installing propane tanks for gas standby.

--Most of our plants are now operating on either oil or gas. Propane tanks have been installed in some plants as insurance. There is a trend to shift from oil to gas. Several plants could switch to coal, but requirwments would be so large as to make logistics almost impossible.

Some companies cite the difficulties of converting to coal:

--We have no plans to move to coal, because rapid changes in steam loads do not lead themselves to coal fired boilers.

--Our present equipment is not suitable for coal without excessive alterations.

--Our energy is supplied by electricity (30% of total), gas (30% of total), and coal, oil, and propane. We cannot go to coal in many locations due to our small requirements. Such units would probably be shut down if coal were mandated.

Several companies recommended that liquid fuels be reserved for mobile units and that alternative sources of energy (primarily nuclear and fluidized bed coal combustion) be developed for stationary equipment.

In view of ever-decreasing supplies of hydrocarbons, several companies strongly suggest that we distinguish between fuels that can be used for stationary equipment and those required for mobile equipment such as airplanes, tractors, and heavy construction equipment. A representative statement follows:

> --For the mid-term, the country must conserve portable fuels (liquids primarily) for portable or mobile requirements such as farm tractors, airplanes, and construction equipment. We need to develop nuclear energy (electricl) for stationary energy uses.

As stated above, in addition to nuclear power, many companies urge that fluidized bed coal-fired power generation equipment be utilized to provide as much energy as possible for stationary uses. By developing alternate fuels for stationary equipment, more petroleum fuels would be available for portable equipment.

Liquid synthetic fuels and battery-generated electricity are recommended for portable units, automobiles.

Companies recommend that, as soon as economics dictate, liquid synthetic fuels be used for portable units and automobiles.

> --We predict that liquid fuels from coal will come along first. We should be building units now to have synthetic fuels in the 80's. The technology is ready now to use them as soon as economics dictate.

--We expect the crunch in availability and cost of portable fuels in the mid or late 1980's. About this time, we expect the cost of synthetic fuels to be competitive with petroleum fuels.

--A synthetic fuel industry could be created by a simple law that says by a certain date, say 1988, 2% of all liquid fuel must be of synethic origin. It would not be necessary to tell industry how to do it or what price the synthetic fuel would be, just a requirement that if industry wished to sell liquid fuels in 1988, 2% of that fuel must be synthetic.

--The manufacture of liquids from domestic solids is held back because our political arm does not choose to make this commercial. There is a need to resolve government inter-agency conflicts related to energy production. The government is ignoring technology already available which would insure our domestic energy supply, independent of imports. The investment cost of oil saved by the end of the 1980's by redesigning the auto will be at the rate of $40,000-$50,000 per barrel per day of oil saved. This may turn out to be twice the cost of investment to generate this same liquid energy from solids. It is foolish to push the efficiency of the automobile to a cost where the customers cannot afford to buy the car. In the present program there is a self-destruct element which eventually will be either changed by Congress or blamed on industry and OPEC.

--Nickel-zinc system is promising as a power pack for mobile transport. Has attractive watt hour/lb. performance. The market is estimated at 20-30,000,000 limited use vehicles for urban areas. Present lead-acid batteries (very heavy) provide 40-50 mile radius. With nickel-zinc this radius is increased to 100-200 miles. New battery systems will provide future markets for lead and zinc.

--Batteries for electric-powered vehicles. DOE should provide funding for this development because of the high risk involved with the future of electric powered vehicles.

Without alternate energy sources for stationary equipment and without synthetic fuels to complement and eventually replace petroleum fuels, some companies claim that their business will cease.

<u>R & D activities have been undertaken to develop alternate energy forms for use as chemical feedstocks.</u>

Most chemical companies and several companies with plastics divisions clearly stress the importance of a continued supply of chemical feedstocks. There is overall agreement that petroleum is more valuable as a feedstock than as a fuel - both because there is greater flexibility in fuel and because only a very small percentage of total crude oil is used by the petrochemical industry:

--We see petroleum moving in the direction of feedstock supplies rather than to fuels.

--We expect the use of petroleum for chemical feedstocks will always displace its value as fuel oil, because less than 5% of the total crude used goes into feedstocks.

--Our entire production is dependent on chemical feedstock availability. Feedstocks will be available for a long time since feedstock producers can bid their raw material out of the gasoline pool.

--In the chemical business, feedstocks have to take precedence over fuel.

--We are basic in styrene. We foresee no problem with chemical feedstocks because petroleum will always be of more value as feedstocks than as fuels.

Consequently, at present, industry does not see real price competition between chemical feedstocks and the use of petroleum as fuel. Since less than 5% of the total crude used goes into feedstocks, there is little interaction between chemical feedstocks, raw materials supply, and the use of petroleum for fuel, especially since the chemical industry is better able to absorb slightly higher costs than the fuel industry.

However, as the supply of petroleum dwindles, the percentage of petroleum used for feedstocks will increase. This anticipation has led to increased R & D aimed at making a transition from the exclusive use of oil and gas to the use of alternate energy forms, primarily coal, for chemical feedstocks.

--We have projects in R & D to utilize C3 and C4 by-products from our ethylene plant. Liquid by-products from coal gasification are especially valuable for some petrochemicals because of their aromatic content.

--Between 70-80% of products are based on hydrocarbons. We are interested in the oil shale task force from a viewpoint of possible supply (of petroleum for feedstocks).

--We need raw materials. We are almost totally independent in iron ore, limestone, and coal. We are concerned about the supply of hydrocarbons because of our plastic molding business.

--As the costs of oil and LPG go up, ethylene costs will increase more rapidly than propylene and butene. This puts economic pressure on a shift to lower priced feedstocks.

--One division buys resins from petrochemical companies. It would be affected indirectly as the supply of feedstocks (or steel) changes or diminishes.

Some companies express fears concerning the supply of feedstocks, primarily with regard to the supply of natural gas and petroleum and the cost of ethylene, aromatics, and olefin.

Since there are 350,000 people employed in the primary plastics industry, an industry that depends on about 1% of our total crude, this industry urges that supply be continuous and affordable.

--Our major raw material is ethylene which is used for vinyl alcohol and acetate, polyethylene, and alcohol. We are basically a natural gas and oil based feedstock company. We are very concerned about supply.

--Supply is very important. It involves synthetic rubber and synthetic fibers.

--Aromatics are in short supply and therefore very expensive.

One company noted that the ethylene and olefin industry overbuilt, resulting in low prices due to competitive pressures. This they say will change by 1981-1985 when the demand for these will exceed supply, causng the price to increase by as much as 50%. For companies producing vinyl alcohol, acetate, polyethylene, etc., this would be a serious problem. Another concern is that since aromatics are already in short supply, their price is escalating above inflation.

Many companies mention factors that inhibit their ability to plan for their energy supply needs.

In attempting to describe their corporate energy strategy with respect to supply, many companies mention factors that inhibit their ability to plan. For example, many companies feel that their plans for the future will have to be held in abeyance until there is more certainty about prices, supplies and government allocations:

--The nature of government pricing policies is an unknown factor and affects the availability of supplies. We have built storage facilities to prevent plant close-down because of lack of supply.

Pricing controls that keep energy artifically underpriced are blamed for severly limiting the availability of supplies:

--Price controls have been limiting oil and gas availability since U.S. companies cannot afford to drill the wells to find new supplies. It is OK for foreigners to make money or get rich on selling oil and gas to us but it is not OK for a U.S. company to make money or get rich. This does not make sense.

--The government must start to develop new resources for energy and deregulate the price of oil to make the new sources competitive.

--Instead of "protecting" people by regulating the cost of fuel, people would be better protected if they were employed in a more constructive way to make liquid fuels from available solids. Synthetic fuels would increase the cost of fuel in the U.S., but would stop the dollar drain and decrease vulnerability due to foreign supply.

However, one company states that artificially controlled gas prices has had a positive effect on its operations:

--With low artifically controlled prices on gas, gas has been our main source of energy.

Since conservation and environmental regulations are constantly shifting, many companies are not sure what kinds of energy sources they will be allowed to use and to what extent.

--Our problem is <u>not</u> in finding gas or drilling for it, but rather with government regulations. DOE says we cannot use our own gas unless it is certified as 533 self-help gas. We have gas sitting in wells, and we cannot use it.

Environmental standards, themselves, are felt to negatively influence corporate ability to respond to energy needs. Time and again, businesses urge a balance between environmental risks and energy needs:

--Expansion of the major utilities has been curtailed because of pollution control problems. The electric utilities may not be able to catch up on their construction programs to the point where electrical energy is available as needed. Therefore, we take future regulations very seriously.

--No governmental decision can do our country more harm than to delay the breeder reactor. The delay is the worst government decision.

--Both the lead and zinc extraction processes require gaseous fuels. On-site gasifiers may not be used if there is too tight a squeeze on sulfur emissions.

Government interference with the free market and other "political" decisions are perceived as impediments to the development of energy technologies:

--The federal government is trying to control supply by regulating rather than by allowing supplies to float in the free market. For example, we were assured that by turning to Mexican gas we would have enough for 100 years. However, the government stepped in (State Department and ERDA) and drove business out of the picture, because they could not allow the import of Mexican gas. The Mexicans wanted only $2.60, and yet the government was willing to spend $3.20 for Arab LNG for the same energy equivalent. Now the Mexicans are mad at us. It could be that some U.S. business will relocate to Mexico.

--The breeder reactor may have been stopped for political reasons.

--We see no electricity problems or oil shortages unless political (world-wide) in nature.

--We believe the government will work toward an assured supply of electricity and gas at the lowest cost because it is vital to the industrial economy and jobs. However, this is a political problem.

ENERGY PRODUCTION AND TRANSMISSION

This section reports on the responses of the 26 companies who stated that they were engaged in energy production or transmission. Information is presented for companies who produce energy only for their own use, for those who produce for their own use and for sale, and for those who produce primarily for sale. Projects described are ones that relate to industrial processes as well as to R & D efforts.

There is a significant move toward energy self-sufficiency.

This is true both for companies producing energy primarily for sale who want to reduce their dependence on foreign sources as well as for consumer product companies who wish to ensure an uninterrupted supply of energy for their industrial operations.

This concern for an uninterrupted supply of energy arises from fears of scarcity, distrust of unstable foreign sources, and uncertainty about government mandated conversions and allocations. Some companies establish or enhance energy-producing capabilities by acquisitions. Many companies also recover and convert internal sources, such as waste heat into useable energy. This use of internal sources of energy is becoming more economical as the price of purchased energy goes up.

Among those companies who produce energy for their own use, gas is the most popular energy source, quickly followed by oil and coal. The major method reported for generating electricity and steam is through cogeneration. Other methods are direct coal combustion and fluidized bed combustion.

Companies who produce energy for their own use report that they have undertaken or have plans to undertake the following kinds of projects and programs:

<u>Gas Production</u>:

--We are drilling for gas in Ohio and Kansas. In the last four years we have drilled 175 wells.

--We have drilled gas wells at one plant, and will expand this if economics are favorable.

--We own some (backup) gas wells, so we can supply 15-20% of our needs.

<u>Electricity</u>:

--We have programs to install electric generators to produce guaranteed 24-hour service of constant voltage electricity.

--We have installed facilities for electric power generation in emergencies.

--We are looking at coal generated electricity to be independent for our own protection.

<u>Ethylene</u>:

--We produce ethylene from ethane (from natural gas).

--We are considering a 1 billion pound cracker to produce ethylene for our polyethylene operation.

<u>Olefins</u>:

--We produce energy from burning nonenes in steam boilers (because of environmental requirements). Nonenes are olefins recovered from the process of making anti-oxidant rubber chemicals.

Steam:

--Production and transmission of steam are important aspects of our plant operation.

--We burn low sulfur coal and oil for steam production. Other projects include: cogeneration; trigeneration (steam, electricity, and low B.T.U. gas); fuel from waste products from paper mill operations; and the production of hydrogen and methane from biomass.

Oil and Gas:

--We have subsidiaries which produce oil and gas, and we are interested in lignite.

Cogeneration:

--Cogeneration will be used at all our plants where it is economically viable.

--We are emphasizing two types of cogeneration: 1) We feed waste steam from turbines bck to other uses (e.g., heating); 2) We use as much waste heat as possible.

--We have cogeneration of steam and electricity.

--With cogeneration, we produce 90% of our electricity needs in one plant and 35% in the other.

--We cogenerate about 30% of the power in our largest plant, using very low pressure steam in evaporation.

Production of Several Types:

--Our sole concern with energy production is currently for our own internal use. We have invested $65 million in recovery boilers used in proper manufacturing. We upgrade biomass through controlled burning pyrolysis, and we recycle city garbage to recover aluminum, steel scrap, and glass. This produces combustibles used in city electric generators.

--We develop all practicable additional sources of energy such as exploration for natural gas, use of coal slurries, conversion of wood wastes, agricultural wastes, and garbage.

Some companies who produce energy for their own use, sell their excess energy. The major methods these companies use are cogeneration, waste heat recovery, and coal-generated electricity. Examples follow:

--Our projects include a move to generate most of the power needed within our own plants (with ties to adjacent plants to supply or trade energy back and forth), and cogeneration, including the sale of electric power from our refining operations. There are places where we generate our own power through cogeneration, and places where by-product energy is sold to other companies (this includes carbon monoxide from iron smelting). Excess heat from our cement kilns is used for electric power generation. We are looking for markets for waste heat from our cement, gypsum, and tile operations.

Among companies who produce energy primarily for sale, projects have been undertaken in: nuclear reactor development and fuel production, fluidized bed combustion, cogeneration, and coal gasification. New storage techniques are also being studied.

--The basic involvement of our company is in all aspects of converting any fuel to electricity. Breeder reactor development is important to this conversion. Also, light water reactors convert fuel to electricity. We work on mechancial drive with respect to converting fuel to useful energy forms such as applicable to the development of aircraft engines. We also work on fluidized bed combustion.

--Three projects involve coal gasification for low, medium and high B.T.U. gas, cogeneration for electricity and steam, and nuclear high temperature capability.

--We are involved in the production of yellow cake (uranium oxide concentrates) used as fuel in nuclear power reactors.

--Underground and cryogenic storage are being studied to provide supplies during peak periods.

For companies who produce energy primarily for sale, exploration activities are still an important part of their corporate energy strategies.

Exploratory programs are being undertaken for oil, gas, coal and oil shale:

--We do conventional production of oil and gas and new techniques such as EOR. Our exploratory activities include coal and oil shale...

--We are aggressive about finding new oil on land in the lower 48 states... We have a major effort to recover gas from geopressurized mines and from coal seams.

There are also plans for the commercialization of oil shale and tar sands:

--We have plans for a commercial oil shale plant. We expect to be able to produce oil at a slightly higher cost than Mid-East oil by 1990. We are working on tar sands, hoping to produce oil by 2000.

The concern for more energy independence is apparent in the R & D efforts of both energy-producing companies and primarily consumer product and other manufacturing companies.

Of the 26 companies engaged in R & D on energy production and transmission, 7 companies have major projects devoted to one of the following areas of concentration: geothermal, solar, mining, catalysts, or metallurgy (for petrochemical production equipment). Fourteen companies report that they are pursuing a variety of medium level R & D projects on general production techniques, such as biomass, solar, wind, geothermal, hydroelectric and nuclear. Other companies report medium-level R & D efforts restricted to single technologies including combustion research, high sulfur coal, off-shore gasification and liquefaction, and a non-freeze heat transfer fluid for solar systems.

The following examples demonstrate some of the R & D being undertaken:

<u>Major Efforts</u>:

--We have a major contract with DOE to work on new concepts of geothermal energy.

--We have major solar energy involvements (including a recent DOE contract) to develop solar energy for industrial process heat in one of our processing plants.

--We pay major attention to new techniques for coal mining and develop special techniques for mining uranium. By computerizing reserves, we assist in the planning of our mining operations for coal and uranium. This takes some of the guesswork out of mining. Also, we are working on continuous mining and conveyor systems.

--We have a major project on a catalyst to improve yields of desirable end products (petroleum).

--The bulk of our R & D is aimed at the study of metallurgy (for petrochemical production) including mechanisms of cracking, fracturing, corrosion (inside and outside), low temperature effects, etc. We have special problems with H_2S and CO_2.

--We have a major effort in increasing reserves and the recovery of petroleum, natural gas, coal, uranium, and geothermal and other energy sources.

--We have a very strong R & D component to develop an alternate fuel source from coal that is more environmentally acceptable. We are heavily involved in the S.R.C. process and demonstration plant. Also, we are working on fluidized bed combustion.

--We have R & D on EOR, oil shale, gasification, liquefaction, and biomass, all as alternate fuels.

--We have large sources of biomass materials and the technical capability to produce char (black oil), oil and gas. We have a large R & D effort on biomass to produce char, gas and oil at competitive cost and capable of meeting emission regulations.

Medium Efforts (i.e. those efforts not explicitly noted by companies as major)

--We are searching for optimum routes to convert various fuels to useful energy at the lowest possible costs.

--We have a substantial exploration program for gas and coal. We are looking at an expanded cogeneration facility and evaluating a wind machine. We also have a joint solar voltaic project. We are doing some research on the abatement of hydrogen sulfide emissions at the older geothermal plants.

--We are doing R & D on the generation and utilization of hydrogen, fuel cells (with DOE), magnetohydrodynamics (MHD), combined cycles, cogeneration, and photovoltaics (solar cells).

--We are looking at cogeneration and solar panels for in-house energy production. We require considerable process steam. We are following fuel cell development. Where applicable and economic, cogeneration and solar will be used.

--We are doing R & D on poly alpha olefin, used as a non-freeze heat transfer fluid, especially designed for solar systems. It has a limitation of about 600 F. Also, we do R & D on nonenes and combustion.

--We have a DOE contract to develop geothermal energy. We do R & D on the utilization of waste, vegetable waste, and animal waste. Our direction is toward anaerobic generation of methane. We have a pilot unit in operation using potato wastes.

--Our R & D includes work on the improvement of coal-fired boilers, pollution control in stack gas effluents, efficiency of electrical operations, nuclear research, hydroelectric, solar, wind, and municipal wastes research.

--We do R & D on high sulfur coal, including the use of SO_2 produced in the combustion of high sulfur coal.

--We are designing and preparing to build off-shore liquefaction and gasification (of liquid methane) plants.

--We are working on the gasification of coal. The substitution of oil for gas is being looked at, along with coal slurries. Also, we are looking at coal generated electricity for the purpose of enhancing our independence.

--We are looking at feedstocks for the future and developing processes to use them for new businesses, e.g., biomass, synthesis gas from coal, etc. We are considering cellulose conversion to ethylene.

--We are working on seismic analyses and techniques for the discovery of oil and gas pockets at tight stone formations and for smaller reservoirs at deeper levels. We are studying hydraulic tracing, water flooding, and EOR techniques, including chemical.

--We are working on new and innovative processes for the recovery of oil from oil shale and tar sands. Residual oil fields are being developed. We are studying the use of coal for chemical feedstocks, activated carbon and carbon black. We are considering on-site low B.T.U. gas generating facilities.

--We are a member of the American Gas Association, which does R & D on gas production and transmission.

--We are looking at hydrogen as a fuel. This includes the production of hydrogen from water using high temperatures from fusion or from high temperature solar collectors. We are also working on methane production from biomass, uranium exploration techniques, and uranium enrichment techniques.

Minor Efforts

--We pay some attention to solar energy.

--We have a minor effort...on solar kilns for kiln

> drying of lumber for furniture. The cyclical nature of solar is not considered a deterrent in this application. We could get moisture down to 12% and thus reduce our overall energy requirements. We have a small effort in biomass. We burn wood scrap.

In addition to mentioning particular R & D efforts, several companies described their future concerns with respect to energy production and transmission. These concerns relate to corporate development of particular technologies as well as to the role government will play in such development. For example, one respondent expects the government to assure mid-term supplies of electricity and gas, while another expects government policy vis-a-vis EOR to change in the mid-term, making it more economical. It is recommended that government study the coal distribution system, and there is uncertainty with regard to how the government will interpret the law on "best available technology" concerning high-sulfur coal. The future of liquefied natural gas is considered "economically uncertain". Speculations are also made about some new fuels. One firm states vaguely that hydrogen fuel, with fuel cells, may become important. As discussed earlier one oil firm plans a commercial oil shale plant, to be able to produce oil at a slightly higher price than Mid-East oil by 1990. They are also involved with tar sands, and hope to produce oil by 2000. Another firm expresses interest in a network of "soft energy" (e.g. solar, wind, geothermal) systems. They believe that a system of linkages is essential if "soft energy" is to become important. Another firm looks forward to the long term development of an "electric economy". Examples of some of these remarks follow:

Nuclear

--We hope to activate two nuclear plants, each providing 1000 megawatts. Our hydropump storage plant, also 1000 megawatts, should start in two years.

Renewable

--We are interested in a network of soft energy systems. By soft energy we mean solar, wind, geothermal, etc. Soft energy will become important only when many such sources are linked in a system. For a control system for a soft energy system, computers, etc. will be needed.

Electricity/Cogeneration:

--We expect to install cogeneration facitities at four or five more locations. We have facilities now in three major U.S. locations.

--We expect the government to assure a supply of electricity and gas for the mid-term. For the long-term, we look forward to the development of an electric economy, though we may still need some hydrocarbons (gas or propane) for carburizing steel.

Coal

--There will be a need for a coal distribution system to provide on-site gasifiers with feed. Pipeline distribution is a possible answer. The government should be studying this problem.

--As regards handling high-sulfur coal, it is presently not known how the government will interpret the law on "best available technology".

Oil, Gas

--We obtain 15% successful wells of the total drilled. Less money is going into off-shore leases since the benefit:risk ratio is lower on land. With new seismic analysis, we expect to maintain the 15% success rate. New wells will be for smaller pockets of oil at deeper levels.

--In the mid-term, we hope to have alternate methods for (oil) transportation, including pipelines, trucks and barges.

--For the mid-term, we expect policies to change so that it wil be economical to produce oil by EOR means.

--The future of LNG is economically uncertain.

Other Fuels:

--Hydrogen fuel in fuel cells may become important for the future.

The development of pipelines for a variety of fuels and other means of transportation for coal and oil are seen as important transportation problems.

Some companies describe the difficulties of coal transportation especially in winter, and express hope for mid-term development of alternate means of oil transport. There is interest in developing coal slurry pipelines from Alaska, Montana, and Wyoming. To avoid or minimize interruption of sources, one company established intra-company procedures for transferring energy between divisions.

The following remarks describe current or planned transportation-related projects and corporate concerns for improved transportation capabilities:

Projects

- --We produce, use, and sell electrical transmission equipment.

- --Our ... division has active projects on transportation of coal slurries by pipeline and fluidized bed combustion.

- --We are developing technology for low cost installation of plastic pipe.

- --A key area for reliability of service to (petro-chemical) customers is the study and selection of steel used for pipelines and fittings, etc.

- --We have a project concerning gas transmission lines which tie into interstate pipelines.

- --We are increasing attention to (petroleum) transportation with special emphasis on water transport, including oil tankers.

- --We develop liquid natural gas tanker and transportation equipment. We are actively searching for additional ships' construction.

- --Gasification and pyrolysis of biomass allows more oxygen in the destructive distillation process. The production of char or black oil from wood gives alternate storage and shipping of energy.

Concerns

--The transport problem for coal is an important factor in getting the fuel to the user (most of the coal is in the Appalachian region and problems of weather can be severe).

--We are concerned about transporting coal from the mines to where it is needed.

--Transmission of steam and electrical power for the pulping and paper making operation is a key factor.

--Fossil fuel delivery is critical.

--We have established inter-company procedures for transferring energy between divisions to avoid or minimize interruption of sources.

--Our (mineral) operations in some areas are completely dependent on motor transport. The '78 strike was a major blow.

Many factors impinge upon corporate ability to plan for energy production and transmission.

Companies stress that uncertainty about the availability and price of energy reduces their capacity to plan for energy production and transmission needs. Among the examples they provide are the uncertain rate structure for electricity and the unpredictability of price controls. The number of permits required and delays in getting permits also seriously hinder corporate energy production efforts.

Industry feels that it is caught in the cross-fire of inter-agency conflicts, principally between DOE and EPA. Better co-ordination between DOE and EPA would reduce the number of conflicting regulations industry must meet.

There is concern over legal entanglements that can ensue from providing other companies with surplus energy. Once a company is defined as a utility it becomes subject to regulations that inhibit its ability to carry out energy producing activities such as cogeneration. One corporate executive described the problem this way:

> We are concerned about how far we can go in selling excess steam or electricity from our refining operations before we encounter legal problems because we are acting like a utility in supplying energy to others.

There is also concern over how the government will interpret the law on "best available technology". As mentioned earlier, one company points out that this is particularly important in respect to the handling of high-sulfur coal. Industry urges that practicality and reasonable considerations be used in determining the kind of technologies that will be allowed and suggests that cost-benefit analyses be performed that analyze the amount of environmental gain against economic and energy costs.

The following remarks are representative of industry concern with the ways in which government impacts on corporate ability to produce and transmit energy.

Electricity

--As government interferes with rate structures, the need for independent electrical generating capability becomes more important.

--Major concerns relate to the delays in getting approval (state) for nuclear plants.

--Government policies have nationally affected light water reactor operations. They have made that source of energy non-profitable. EPA regulations are a serious problem. EPA should be forced to base its regulations on supportable, relevant data.

Oil, Gas

--We believe that there is as much oil and gas not found yet as has been found to date, but it will cost more to find it and get it out of the ground. Today, DOE pricing policies are more important than underground reserves in obtaining oil. As prices go up, more oil will be found.

The government (DOE) plan on EOR is an "excellent disincentive program". We must make EOR economically attractive since it is not technologically proven.

--Our concern is that DOE has not moved rapidly enough or effectively enough to develop oil shale and geopressure methane or smaller gas pockets.

--We would consider producing more gas if government regulations would allow unrestricted transportation and use.

Synthetic Fuels

--We have coal reserves in the western U.S. We formed a subsidiary....to build a coal gasification project. Gas produced...would have been carried by existing pipeline to California. The project was dropped because of the huge escalation of capital costs in the '72-'75 period and the extreme difficulty in getting fifty or more permits ... About half of the necessary approvals had been obtained when the project was dropped. The company is strongly critical of DOE for not providing better support.

NEW PRODUCTS

This section focuses on new products and R & D for new products which 1) relate to the production of new energy sources or improved utilization of energy sources and 2) enhance energy conservation through improved end-product energy efficiency.

Because of uncertainty about government policies and about the costs and availability of energy sources, most new product R & D is aimed at commercialization in the near or mid-term.

The responding industries feel they can not develop long-range strategies or undertake long-lead high-risk ventures in a climate in which ground rules continually change. Nevertheless, many companies are designing, or redesigning, products and processes to supply consumer and commercial demands for more energy efficiency. Some of these efforts are innovative and some of the R & D, if successful, will represent significant breakthroughs.

Forty-three companies reported that they are involved in R & D on new energy-related products. Twelve companies are doing R & D on products for the recovery of alternate energy sources; fifteen companies are undertaking R & D concerning vehicles; twenty companies report R & D on products for better utilization of energy sources. These projects reflect corporate short term plans.

The main goals of typical R & D programs on products and processes aimed at enhancing energy production are to increase the availability and decrease the cost of electricity, fuels, and feedstocks through conventional improvements and new methods. The energy sources which receive the most attention are nuclear power, batteries, and new or improved methods for the production of conventional and alternate fuels. The following examples are representative:

--Our most important and most advanced new product is our coal fired fluidized bed cogeneration unit to be built by our solar division. The first unit would be gas fired and installed if DOE grants approval to our proposal, submitted some time ago. Other products being considered include modular biomass converters, multifuel stratified charge engines, combined cycle projects, and engines using new fuels such as hydrogen.

--We have government contracts for new coal preparation equipment, fluidized bed conversion, and instrumentation and control.

--We are developing solar panels using some of our stamping techniques. We are developing blades for windmills, with stainless steel blades 130-140 feet long.

--We do R & D in biomass and agricultural and forest residues to supply energy for our equipment. Since 3% of our nation's energy consumption is in agriculture, this is a good area for potential savings.

--We have a wide range of R & D in different energy technologies such as exploration, production, geothermal, refining, EOR, gasification, etc.

--Our R & D that is specifically related to energy is in areas of solar, nuclear, waste, and fossil. With us, research is a product.

--We do some (joint) work supported by DOE on the applications of our materials in photovoltaics. We are ready to design a 100 ton demonstration plant.

--We also work on solar heat transmission fluid, insulation from urethane, and plastics for automobiles.

--We work on alloy reformulation and solar collectors.

--We work on passive solar energy applications, improved prime and storm windows and reinforced concrete with polyurethane barrier layers for insulation.

The major R & D programs related to improved end-product efficiency are concerned with weight and fuel consumption of vehicles, new and improved insulation, and other energy conservation products, such as specialized instrumentation for advanced industrial process control systems.

R & D concerning vehicles

- We spend a lot in R & D to insure vehicle quality even with rapid changes in materials. There is a high risk in pushing "know-how" on materials to new limits. It is also almost impossible to calculate the cost-weight tradeoff in materials.

- We work on urban transit systems, including new bus designs. Other projects are solar energy equipment and applications, nuclear fusion, including engineering inputs to the nuclear test reactor at Princeton University (the biggest Tokomak Fusion Test Reactor in the world).

- Our R & D on facia, to replace metals in car bumper guards, cowling, etc. is designed to cut down on the cost of repairs.

- We are developing new high strength steel for the auto industry, to lower the weight of cars without losing other properties, such as weldability or corrosion resistance.

- We are working on lighter weight equal strength frames for autos and trucks.

- Our R & D includes engineering plastics and new products, many of which are for the auto industry.

- To compete with lighter weight materials (aluminum and plastics), we are developing lighter weight higher strength steels for the auto industry and lighter gauge materials for the appliance industry.

- Other products being considered include modular biomass converters, multifuel stratified charge engines, combined cycle projects, and engines using new fuels such as hydrogen.

- We are working on jet engines for standby and peak power use. We are also working on diesel pumps, aircraft engines, fuel cells, helicopters, electric wire and insulating materials, electric control systems, computerized systems for energy use control, automotive electronic control systems for optimum energy use, wind turbine generation, residential and commercial solar systems, nuclear fusion, gasification, etc.

- We do vigorous R & D on improved auto transmissions, auto air conditioner compressors, and commercial and home air conditioning and heat pump units.

- We have active projects to develop aluminum heat exchangers for automotive use, use of more plastics and resins, different coatings in autos, and power chains for new transverse small auto engines.

- We develop pumps that can be used in deeper wells (submersible type) and at higher temperatures.

- We influenced the development of high torque rise diesel engines in combination with fewer forward gear speeds (6 vs. 13). With 1 drive line (vs. 2) these avoid parasitic power losses.

- We are working on modified or new internal combustion engine fuels, burner oils or solid (powdered) fuels, etc.

- We do major R & D on friction modifiers (potential gasoline savings of 1-5%), low viscosity partially synthetic lubricating oils, and gasoline additives.

- We work on catalytic combustion for a wide variety of fuels and on a total range of fuel cell packages.

- A major project is to develop a high energy density battery system with very large performance advantages over any product now on the market (e.g. the present lead acid battery, rated at 15 watt hours per pound, would be replaced by a system capable of 50-100 watt hours per pound). DOE is funding part of one phase of this project. Our can business is being forced from steel to aluminum.

Other R & D for more efficient use of energy

- We give special attention to the improvement of the conversion efficiency of our products.
- We do some high level R & D on the production of special lubricants.
- We are working on new siding for buildings.
- We are developing electrical spot heating devices (parabolic, panel, and spot).
- We are looking at materials for Enhanced Oil Recovery, not chemicals, but hardware. We do R & D on electronical steel. Also, we work with the auto industry to develop front wheel drives and other capabilities.
- Our R & D has increased tolerances on voltages and amps required to operate computers, on the basis that future supply will be variable and of decreased quality. We are attempting to improve performance per kilowatt. We expect greater use of computers to control all types of operations such as autos, heating, etc. We are concerned with photovoltaics, and solar cells of gallium arenide.
- We work on heat pumps as supply back-ups for solar and general water heating. These require specially designed motors.
- We also work on coatings to improve insulation, methane generation from manure, and computer programs to determine the size of solar water heating systems required.
- Our thermoplastic rubber (TPR) does not require vulcanizing, thus saving that energy.
- We also work on solar heat transmission fluid, insulation from urethane, and plastics for automobiles.
- We do R & D on super-conducting systems and new types of heat pumps (DOE contract).

- We are improving the efficiency of our entire electrical line, including switchgear, transformers, motors, and lighting equipment. We are improving existing batteries and doing new work on photovoltaics for recharging batteries in inaccessible locations such as buoys.

- Our appliance division is extremely active in reducing the energy consumption of washers, dryers, ovens, ranges, micro-wave ovens, portable appliances, etc.

- Our evaporative coolers (now using 1/3 of the energy of air conditions) are selling in great volume. Further energy efficiency is needed.

- We design bearings which use less energy and lower torque.

- We develop new products to fit the new and more energy-efficient appliances.

- We develop new processes to reduce the tremendous capital and energy requirements of some of todays processes.

- Water based binders for paints and inks save energy and solve some EPA problems.

- We have a program on energy control of products and processes.

- R & D is critical in maintaining and expanding our business with respect to designing, manufacturing, installing, and operating more energy efficient industrial equipment for drying, process heat, heat treating, and steam turbines for electricity using waste heat process heat.

- Our pulse-boilers have 96% efficiency on continuous operation and 93-95% on intermittent operation compared to ordinary boilers with 80% and 50-60% efficiency respectively. These will provide a large energy saving to homes using gas-fired hot water heating, and with more R & D could be adapted to hot air heating.

- Also, we are working on electronic components for automotive fuel saving devices.

- One of our divisions is active in redesigning products (appliances) to make them more energy efficient.

- We have active projects to develop aluminum heat exchangers for automotive use, use of more plastics and resins, different coatings in autos, and power chains for new transverse small auto engines.

- We are working on new laundry detergents.

Although, in regard to new energy-related R & D, the focus is on short-term efforts, eight companies commented on their plans for the mid and long-term. Of these, four stressed conversion from present energy sources to better energy supplies, and four described equipment for better energy efficiency.

<u>Energy conversion for the mid and long-term.</u>

--Some interesting work is in progress on the conversion of carbon to alcohol...The future for lead and zinc will be in advanced battery systems.

--Our interest in producing fuels from carbohydrates could accelerate depending on new technology, economics, or political decisions affecting economics.

--We expect to be involved in ocean mining operations and ocean thermal energy conversion.

--The production of transportable liquid fuels from alternate sources (coal, shale, heavy oil, biomass, etc.) will require new conversion and treatment processes and perhaps new systems for utilization.

<u>Energy efficient equipment for the mid to long term.</u>

--More intense efforts will be needed on new products for energy efficiency, energy conversion, energy transport, etc.

--We will be doing R & D on friction studies, more efficient combustion for furnaces, and new processes such as powdered metals for antifriction products.

--We foresee more automated farming and putting farms on a self sufficient basis for energy.

--Our R & D will include the above, ore processing, improved generators, turbines, and transmitting systems, voltage regulators, circuit breakers, and pumped hydro storage.

--We will pursue R & D on electronic components for automotive fuel management systems and micro processors and integrated circuits for these systems.

Opinions rage from extreme pessimism to extreme optimism on the ability of these new and improved technologies to reduce the nation's dependence on imported oil. On the pessimistic side, one corporate representative stated:

--Company energy task forces, based on analysis of world energy supplies made their own conclusions: coal would not grow as fast as predicted; atomic energy would not grow as fast as predicted; zero growth in shale, tar sands, coal liquefaction and gasification and minus zero growth in solar.

But a more optimistic opinion was:

--If we have sufficient incentive we know that we can make hydrocarbons from water, air and sunlight. It is even possible that energy will be so plentiful it will be free.

Companies actually working on these problems are enthusiastic about the possibility of contributing innovations which will reduce dependence on foreign oil. However, nearly all companies stress that government regulations are a major barrier to innovation. As one executive stated:

--Innovation is 5% invention and 95% commercialization. The inventive component is "alive and well" but the commercialization component can't proceed due to diversion of capital and high risk caused by uncertain governmental regulations. Long term R & D is being abandoned since inflation doubles its cost and capricious regulations can result in large capital losses.

Government imposed standards are often perceived as a disincentive to innovations.

Many companies report that up to 50% of their R & D is devoted to meeting government mandated standards, and that this causes diversion of capital from new product, including energy-related, new product innovation. Although there is agreement, in principle, with the government's overall goals, there is little agreement and much resistance to the often shifting, mandated means of achieving these goals. Most companies repeatedly emphasize that with the freedom to develop their own methods of problem solving, they would be able to solve the problems most troubling government and society. With regulated methods, they claim they lose much of their capacity and incentive to invent better products and processes. Typical statements to this effect are:

--We are concerned about uncertainty, including the fact that the future for new products is subject to government regulations, but the ground rules keep changing. Instead of encouraging, DOE is deterring innovation because industry cannot see which way DOE wants to go. Mandated use of the "best available technology" is far from optimum in terms of economics or use in a given situation.

--EPA controls many R & D company operations by environmental regulations. There is no such thing as zero risk. We need a balance between benefit and cost.

--We are concerned about government's present concentration on short-term problems. There is uncertainty associated with prospects of continued funding of government projects, since many of the new product programs are high-risk and require government support. We are concerned that legislative or regulatory changes often alter our business potential.

--We began R & D work about 10 years ago to develop products (petroleum sulfonates) for miscellar enhanced oil recovery. Two years ago we completed a multi-million dollar production unit to produce a series of petroleum sulfonates for the oil industry. Government price controls and proposed regulations have prevented oil companies from obtaining economic returns from this, and our plant has been idle, except for (some small production).

--The costs of EOR-R & D and plant overhead totaled more than $1 MM, i.e., 20% of total company profit (i.e., loss[). We may never go back to producing for EOR. The present and proposed regulations are impossible to live with and there is no certainty of an acceptable business risk.

--All direct coal combustion systems have to be consistent with future EPA regulatory activity, but that is a moving target, so far.

--There is uncertainty regarding the continuity of government programs, they are often on-again-off-again.

Some projects were only pursued as the result of government regulations. These included regulations on replacing gas pilots with electric ignitions, changing from steel to aluminum cans, and many changes in automobiles, especially with regard to weight and emissions control. One firm became involved with alcohol production only because of the possibility of mandates or tax incentives regarding alcohol.

--Government's arbitrary and capricious insistence that equipment meet certain minimum efficiency standards narrows industry's freedom rather than allowing for a variety of innovative thrusts to meet the problem. We spend inordinate time on testing to insure that our products have the improved efficiencies, with added costs to the buyer.

--Fuel efficiency regulations force the development of lighter vehicles but the time frame makes this development very costly and also hazardous when one must assure that the resultant vehicles are safe, durable, and completely saleable. Emission laws cause a waste of fuel, yet must be achieved.

--We are part of the free enterprise system and yet we are regulated by a government which does not understand the problems of operating in a free economy. DOE and DOT need not be concerned with making a profit yet they make countless decisions which have a profound effect on a company's ability to make the profit necessary to stay in business.

--Government laws force us to almost double our investment on new products. We must respond to fuel emission laws, emission control laws, safety laws, etc. Because of laws, our R & D must develop products to meet new requirements (emission control, safety, etc.).

--Until we get this (______) regulatory thing off our backs it's difficult to work on the real problems of energy and materials. It will be impossible to build an automobile that will satisfy all the regulations -- safety, noise, pollution, economy, etc.

--We can not make brand new products because of government restrictions.

--Our decision to get involved in the production of alcohol and other fuels from carbohydrates was 75% based on political possibilities, i.e. the mandated use of or tax incentives for the use of alcohol. The decision was not based on economics since the use of alcohol is not economic.

--We work on electric ignition to replace gas pilots.

--Our can business is being forced from steel to aluminum.

One company was encouraged by DOE policies, while another suggested that the removal of price controls would be a major R & D incentive.

--The removal of price controls on oil and gas will greatly increase the amount and applications of pertinent R & D for the development and recovery of additional oil and gas.

--DOE and the energy situation have made it more challenging to make products more efficient and have created markets for new products.

<u>Innovation is still a vital component of many U.S. Industries</u>

Since new products are their lifeblood, most manufacturing companies continue to strive to produce new products in spite of what they consider to be the unhealthy role government plays in their day-to-day affairs. Several large scale projects are planned or envisioned for the future, including:

--The creation of a national grid including DC transmission with DC inputs from wind generators, photovoltaics, etc.

--A nickel-zinc system which is promising as a power pack for mobile transportation. It has attractive watt hour per pound performance. The market is estimated at 20,000,000 - 30,000,000 limited use vehicles for urban areas. Present lead acid batteries (very heavy) provide a 40-50 mile radius of operation. With nickel-zinc, this radius is increased to 100-200 miles.

--A current project related to enhanced oil recovery. Sodium lignin sulfonate is a low-cost formation sealer and, with follow-up steam injection, it is much more successful than other approaches in the recovery of heavy oil.

--Enhanced gas and oil recovery by use of sintered bauxite. The sintered bauxite can be pumped into oil and gas formations to "prop" open the crevices in the rocks to establish channels for free flow of oil and gas (cavity maintenance).

--Commercialization of electronic components for automotive fuel management systems.

--Conversion of various substances to fuel, including alcohol from carbon, fuel from carbohydrates, liquid fuels from coal, and energy sources from various thermal sources.

Of the 25 companies which produce new products directly related to energy, 7 produce equipment for the location and recovery of new energy sources, 4 produce insulation equipment, 6 make a variety of products concerned with energy conservation and production, and 4 have introduced new vehicle-related products including multifuel stratified charge aircraft engines.

Six companies are working in other areas, including ceramic refractory furnace units, water treatment devices and systems, low energy laundry detergents, nickel-zinc power packs, railroad car wheel bearings, and energy-efficient plant designs.

Three companies mentioned specific new processes, including new kilns for secondary recovery of lead, a new ultraviolet curing process, and a waste water purification system which helps utilities and oil companies meet water contamination standards.

The following statements provide examples of new products or processes industry has undertaken:

New Products and Processes to Enhance Energy Production

--We produce sodium lignin sulfonate for EOR and hardware for nuclear plants, solar collectors, shale processing, oil production, etc.

--We produce geothermal pumps, array processors (to determine the presence of oil), underwater pipeline positioners, and helicopter flight control systems for off-shore drilling.

--Our new and higher efficiency products include drilling fluids for oil, gas, geothermal and other sub-surface energy sources, well completion materials and equipment, and techniques and materials primarily for oil and gas production and stimulation. We also work on in situ uranium leaching.

--New tools and techniques for drilling have been developed with instrumentation which provides logging while drilling (this reduces the need for coring) and also provides directional control particularly for offshore slant-hole drilling.

We provide bits for coal and uranium operations. We have fabricated equipment which has drilled a 16 foot diameter hole and now have out bids with private companies to drill a 20 foot diameter hole. These holes are cased as they are drilled. A major utilization will be in the methane release program on coal veins by horizontal drilling from these large holes.

--We produce mining equipment, air compressors, gas lines, pumps, drilling equipment, waste material compactors, and refining equipment.

--We produce gas turbines that will operate at temperatures as high as 3000 F, as compared to the present level of 2600 F. Also, we produce super conducting systems, carbonate fuel cells, solar heating and cooling equipment, improved lighting, appliances, motors, and pumps, and work on MHD and the Tokomak reactor program.

--We produce electronic combustion controls for auto engines, the Beacon system (to burn coal in modified rocket engines; this removes 85-90% of ash as slag), low NOx burner for boilers and perhaps CO + H2 with another company. Also, we have an <u>in situ</u> method to recover heavy oil or oil from tar sands. And, we have ocean bottom oil and gas well controls which operate at 2000 foot depths.

New Products for Insulation

--We produce new insulating products and plastics for autos.

--We produce ingredients used by insulation manufacturers, chemicals for EOR, and alcohol or butane dial as fuels from carbohydrates.

--Our improved prime and storm windows reduce air leaks and convection losses. We have added a polyurethane barrier to reinforced concrete for heat conservations. We also produce materials for passive solar energy applications.

--One very recent product, thermalon, provides for insulating interior surfaces of windows.

New Products which use Energy More Efficiently

--We produce new products for utility metering, and we produce new heat pumps.

--Energy conservation products represent a significant growth area for us. This includes thermostats, heat pump components, and energy efficient motors.

--We produce energy conservation products such as turbo-machinery.

--We are vitally involved with improving the energy efficiency of farm equipment, mechanical trucks, generators, turbines, mining, and solid state electronics.

--We produce water treatment devices and systems to lower the cost and conserve water in plant operations. Our pumping systems reduce energy consumption.

--We produce ceramic refractory furnace units tied in with electric resistance cables in the heart of the furnace. This allows for heat build-up at night and heated air flow during the day. It is controlled thermostatically.

New Vehicle-Related Products

--We produce multifuel (stratified charge) engines for flight vehicles, designed to burn gasoline, jet fuel, and marine diesel fuel. The long term interest is to maximize the availability of portable fuel.

--Our nickel-zinc system is promising as a power pack for mobile transport. It has attractive watt hour per pound performance. The market is estimated at 20,000,000 - 30,000,000 limited use vehicles for urban areas. Present lead acid batteries (very heavy) provide a 40-50 mile radius of operation. With nickel-zinc this radius is increased to 100-200 miles.

--Our redesign of railroad car wheel bearings has reduced rolling resistance of these bearings.

--Fiber reinforced plastics (FRP) cut down on the weight of cars.

New Miscellaneous Processes

--We have developed new kilns for secondary recovery of lead.

--We have developed an ultraviolet curing process.

--We have developed a waste water purification system which is being sold to utilities and oil companies to assist them in meeting contamination regulations on water discharges. These may have importance in the future to shale oil operations.

RESPONSIBILITY FOR ENERGY STRATEGY

Approximately 75% of the respondent companies report that one individual, several individuals, or a group or committee has responsibility for the formulation of energy conservation and/or corporate energy strategy.

For almost half of the group of companies interviewed, one or sometimes two individuals have primary responsibility for energy conservation strategy. The level of appointment varies from a staff level person to a corporate vice president. Frequently companies have directors of energy programs who report directly to a corporate vice president. Sometimes these individuals have company wide athority to implement energy programs, but frequently their athority is one of "persuasion" and they must sell conservation projects to the company divisions or act mainly in an advisory capacity, often with the support of top management. In many companies, even though one individual has a primary role in the energy area, responsibility for conservation or product development may reside at the plant manager level.

Twenty-seven companies identified an energy conservation committee, council or group as having primary responsibility for formulation and implementation of energy strategy. In some instances these groups have formalized structure and function and authority to implement policy, while in other companies they operate in an advisory capacity and then authority is "implied".

Approximately 15% of the interviewees report that their energy strategy is decentralized and each operating division autonomously develops energy strategy.

Another group of companies report that they have no single point of responsibility for energy strategy, and that this may vary from plant to plant and from problem to problem.

IMPACT OF THE NATIONAL ENERGY ACT

The details of the National Energy Act (NEA), passed by Congress October 15, 1978, were made public just before the on-site interviews were being conducted so that respondents had had little opportunity to evaluate the impact of this legislation. (The interviewers had copies of a DOE Information bulletin which they left with company representatives who were interested in it.)

However, only 10% of those interviewed made no comment whatever about NEA impact or stated that they had been unable to study it. Approximately 20% of the respondents feel that it is too soon to tell -- that the interpretation of the act and the regulations to implement the legislation will determine its impact. However, fully 25% of the company representatives see NEA as having little or no effect on their companies. Two interviewees felt that their companies had anticipated many of the provisions -- i.e., had already employed conservation measures, and/or switched to coal. Thus they felt they would experience little impact. Most of the remaining companies see NEA as potentially having a major impact. Only two of the total group see this effect as largely positive. The others see it as chiefly negative, or as a mixed blessing at best.

A number of general criticisms of the bill were made: "The act is poorly conceived;" "It does not include long range plans and clear goals;" "It estranges government and industry;" "It is not broad enough;" and even "It will slow down economic recovery in the country -- negate investment plans."

A number of respondents are pleased with the deregulatory aspects of NEA and expressed the hope that a free market will ensue. At the same time, many are unhappy with the increased government regulation they see represented by some of the provisions of NEA. A number of interviewees feel that the increased reporting required will be onerous and costly -- both financially and in terms of manpower, which could better be used in energy conservation, for example.

Three interviewees are concerned that the act might tend to retard development of nuclear energy.

Several interviewees think the NEA may have a positive impact in accelerating R & D, but several others feel it will have little effect in this area.

Many companies also have more specific concerns about particular aspects of NEA which are discussed below.

Energy Conservation

Some companies see conservation as the main thrust of NEA while others consider that since they have already been implementing conservation programs, this aspect of NEA will make little difference. While some respondents feel it does not go far enough, a number of respondents see the National Energy Conservation Policy Act as beneficial because conservation efforts will be encouraged and supported and there will be incentives to produce more efficient products. However, while some companies may benefit by producing more fuel efficient appliances, one respondent mentioned the possibility that those that sell energy might be adversely affected by stringent conservation by consumers.

Coal Conversion

The Power Plant and Industrial Fuel Act of 1978 elicited the greatest number of negative comments of any area of of the NEA. Some companies which have never used coal feel that if they are forced to shift to this fuel the results could be "cataclysmic". This conversion is seen as causing major problems:

- Who will supply all the coal?
- How will coal be transported from the source to the user?
- Shifting to coal is an economic loser.
- Coal has limitations for use as process fuel in some company operations.

Some companies previously had shifted away from coal and now will have to shift back. As one interviewee states, "When EPA came into being, -- we spent a fortune to change from coal to oil -- with no way back." Another company is already utilizing coal but feels efficiency cannot be improved because of environmental constraints. One company reports having anticipated this development and shifted to coal, with concomitant economic and transportation problems. At least 15 interviewees feel that the major concern with this provision is an economic one.

Companies that market products such as coal boilers or air monitoring equipment feel that they may benefit from this aspect of NEA.

Public Utility Regulatory Policies

The consensus of those respondents who commented on this aspect of NEA is that "overall increased cost of electrical energy will undoubtedly occur" and be passed on to the customer.

Again, some companies will not be greatly affected by this part of NEA while others, for example, those who produce cogeneration equipment and systems, may benefit.

Natural Gas Pricing Regulation

The Natural Gas Policy Act of 1978 provides for price controls, deregulation of certain gas, and incremental pricing to industrial users.

Many companies feel that the increased price of gas will aid considerably in ensuring its supply and may even stimulate more drilling and investment in gas. However, other companies feel that gas price is increased without result benefits and several feel that immediate deregulation is necessary. Companies that are largely dependent on natural gas will be affected adversely, and they will be forced to raise their prices to consumers. They also feel that incremental pricing is very disadvantageous to them.

Energy Tax Act

Seven or eight interviewees commented on the Energy Tax Act. In general their comments are favorable and for some companies, an increase in sales of their products might be expected. However, the fact that tax credits are not retroactive for expenditures before the law was signed is of concern: "Another case of being kicked for doing a good job before being required to do so." The solar provisions are not felt to be adequate at this time, but one respondent feels that gasohol may be accelerated by the new energy act.

INTERFACE WITH GOVERNMENT AGENCIES

For this section, interviewers asked corporate representatives to indicate the degree of importance of the influence of various agencies on company energy strategy and its R & D component. Interviewers were instructed to obtain specific examples of agencies' actions or policies which have facilitated or inhibited energy-related R & D or commercialization efforts. Respondents were also encouraged to recommend ways agency policies might facilitate or accelerate the R & D - commercialization process.

In recent years, industry has had to devote an increasing amount of its resources to meet the requirements of government directives, regulations, and mandates which continually grow in number and complexity. Dedication of company resources to these demands often seriously impedes the conduct of business both by reducing return on investment and by discouraging productive and innovative R & D activity. Several companies indicate that fully 50% of their R & D is of the "defensive" type which is performed to fulfill government directives.

Frustration over spending large amounts of corporate resources fulfilling government directives is especially keen since the directives are often shifting and contradictory - both within and between departments and agencies. Furthermore, because industry believes that free market conditions are essential to solving national energy problems, price controls, supply allocations, and mandated conversions are seen as impediments to finding solutions to energy shortages.

Industry reports that both DOE and EPA make a major impact on corporate energy strategy and energy-related R & D activity. Therefore, the next two sections will discuss industry interface with these two agencies. Industry interface with other government agencies will be discussed in the third section of this chapter.

INTERFACE WITH DOE

In reviewing the remarks below, it is important to note that the interviews were conducted at about the same time the details of the National Energy Act (NEA) were made public and before President Carter's announcement of phased decontrol of crude oil prices. Interviewers often found that company representatives had not yet evaluated NEA's impact. Many, in fact, who commented stated that they expected NEA would have little impact on their corporate strategies.

Corporate attitudes toward DOE run the gamut from avoidance, wherever practicable: "We have as little to do with DOE as possible" to extremely active solicitation of DOE funding and contract work. Not surprisingly, the more dependent a company is on DOE for funding of its R & D, the more generally positive its apparent attitude toward DOE. One such company, a large firm, states:

As a major contractor on DOE projects, our objective is to serve DOE in all energy fields in which we have technical expertise.

A small, high-technology company states:

About 30% of our sales is in DOE contract R & D. We have no problems with DOE contracts.

Most of the companies that describe good working relationships with DOE state this in reference to specific, individual projects. Many companies directly credit DOE support of these individual R & D projects and contracts, maintaining that they have had or hold promise to have a positive effect on the commercialization of the corresponding energy technologies. However, most companies claim that DOE's policies, actions, and lack of positive leadership have diminished industry's capability to improve the energy situation.

The interviews tend to contain general, rather than specific, statements describing company perceptions of DOE's policies and actions and industry recommendations. These perceptions, concerns, and recommendations are summarized below. They have been listed in decreasng order of importance.

<u>Need for a national energy program.</u> Industry urges that DOE lead the way for a rational, consistent, and comprehensive energy program.

<u>DOE's regulatory impact.</u> Industry feels that through its regulatory agencies (FERC and ERA), DOE has a crucial and generally detrimental, effect on

industry's business operations.

Difficulty dealing with DOE. Industry reports difficulty in dealing with DOE - both because it is seen as an unnecessarily complex bureaucracy and because of permitting and contracting processes that bear on patent and proprietary rights.

DOE as industry - government intermediary. DOE could be more helpful by assuming the role of coordinator between industry and other government departments, including state and local agencies.

Obviously, these major points are strongly interrelated, but the following sections will address each separately for purposes of discussion. Also, it should be pointed out that the National Energy Act (NEA) and the regulations which will emerge therefrom, may have some effect on these responses. The NEA, however, was too new and the corresponding regulations non-existent at the time of the interviews. Indications are that the NEA does not adequately fulfill the respondents concept of a national energy program as described above.

Need for a national energy program

The hue and cry among corporations for a coherent national energy policy competes only with that for free market, rather than government, control of energy price and allocation. Companies believe that price decontrol, the constructive relaxation of severe inhibitory regulatory practices, and the general encouragement of free market operations are equally important prerequisites to solving national energy supply problems. They see the need for a plan which would clearly delineate energy production and technology development, as well as conservation goals for the near-, mid-, and long-term.

Such concerns have nearly acquired cliche status, but industry apparently sincerely believes that government and DOE, in particular, do not, or act as if they do not, understand the commercialization process as it has historically operated to benefit the nation. Long lead times, from five to twenty years, characterize the commercialization of all new, innovative technology, and this is no less true for energy technology. Government programs, practices, and individual policies continually flip-flop, conflict with each other and even apply retroactively. As a result, industry cannot proceed with energy producing or conserving ventures that, due to perceived government created disincentives and uncertainties, are subject to risks which go far beyond normal commercial risk-taking. In short, industry must be able to operate under a comprehensive government policy, reflected as well through DOE, which allows long-term planning for the entire commercialization process, a process which includes innovations through R & D and capital formation and which requires reasonably predictable return on investment commensurate with the attendant risk. Where risk is especially high, and the prospect for payout marginal, a government energy program must provide active support, not only directly for R & D, but in the form of economic incentives such as tax credits and accelerated depreciation.

Regulatory impact of DOE

The vast majority of companies responded that the primary impact of DOE was through its pricing, allocation, and conversion regulations and directives. This impact was cited as mostly negative and counterproductive, although some admitted to the creation of markets for new products brought about by DOE (and EPA) regulations. The corporate exectives interviewed overwhelmingly subscribe to the concept that a free market in energy will ultimately allocate scarce resources far more efficiently than will government bureaucracies.

DOE regulations regarding pricing, allocation, and mandatory conversion of fuels and feedstocks are not separable in the minds of these managers.

One company said:

> Energy, in an economically usable form (natural gas in this case), is essential in the manufacture of our major products. Its price, however, can double without significant effect on manufacturing costs.

According to this company, government policy, as reflected in its regulations, keeps the price of natural gas artifically low while at the same time other mandates dictate the extraordinarily expensive conversion from gas to coal in the company's new paper plant installations. Thus, energy, due to its inherently minor contribution to the finished product, should not be an important strategic consideration for this company. Yet, due to what the company sees as extremely counterproductive regulations, DOE impact on its conduct of business is crucial. In fact, one of the two executives interviewed is personally convinced that supplies of natural gas would become plentiful if price controls are lifted because, he believes, there exist vast reserves in unconventional forms which require high cost recovery techniques. One of his major concerns regarding conversion to coal is that after making the expensive conversion or more likely deciding instead to "sell off the company's paper plants," these unconventional gas resources would eventually prove out and government policy would again "flip-flop". The interview in which these statements were made took place on November 16, 1978. Three days later former DOE Secretary James Schlesinger was quoted as having said "Firms that have shifted off natural gas will be encouraged...to shift back (to gas) rather than burning imported oil."* This example, of course, does not apply exactly to the mandated use of coal in new installations which would have used natural gas, but it does serve to illustrate the validity of the apprehensions of the interviewed executive regarding continual and frequent policy changes from DOE and the uncertainty which results.

Virtually all of the eight-seven companies interviewed mentioned at least one pricing, allocation, or mandatory

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* "The Pressure Shifts Back to Natural Gas," Business Week, December 4, 1978.

conversion regulation as being inhibitory. Some typical statements follow:

- Uncertainty over pricing and allocations are holding up expansions and growth.
- Mandated conversions may put us out of business in some locations.
- The effect of DOE regulations is to increase the cost of energy and to decrease availability of supply.
- Switching fuels requires re-checking the effect on the heat treatment of metals. Induction heating is being studied as a trade-off in metal processing. However, a change of this sort can set off a long chain of experimental work.
- DOE has caused the most desirable fuel to be artifically regulated to the lowest price.
- DOE's pricing policies have not increased, and in some cases have decreased, research in commercialization and production of EOR.
- Pricing policies concerning oil and gas and mandated conversion to coal are crucial to our entire business. We go ahead, slow down, or stop according to the economic impact of such regulations on our customers.
- In heat treating steel, the fuel is both a source of heat and a reagent. Changing from gas to oil to propane requires careful analytical work and testing to assure product quality.
- Price control and allocation of turbine fuels are detrimental to the airlines. We strongly advocate decontrol; a free market will provide needed supplies at the lowest possible price.

<u>Difficulty dealing with DOE</u>

Many companies complain about the complexity of the DOE bureaucracy and the red tape it generates. They speak of the frustration of trying to deal with a department that is continually changing and reorganizing:

- There is a continuous growth of bureaucracy in the company to keep up with that in government.
- Before DOE, we were calling on individual agencies: AEC, FEA, ERDA, FPC, etc. and we were getting direct and meaningful inputs, but now with DOE, finding the right person with whom to talk is almost impossible. Our questions are technical, but we can't get dialogue with our counterparts...The proper people may be there, but we haven't been able to reach them.
- Reporting requirements are very costly and direct manpower away from energy projects.

Two very large companies with many DOE contracts reported to have problems with apparent conflicts of interest:

- Dealing with DOE now is the most difficult it has ever been. I have a jillion personal acquaintances and still cannot get in. The most important problem is conflict of interest, real or implied. A statement defining conflict of interest is needed.
- DOE policy regarding conflict of interest is a major barrier. A company with any background, experience, competence or capability in an area is almost automatically disqualified from government studies or projects. This is a major concern.

Many companies are particularly concerned with the contracting process. At one extreme are companies, and there are many, with policies of avoidance of government contracts. One huge company with an extremely important involvement in energy says:

- Research tries to minimize contacts with government. We conduct no government (sponsored) work in our laboratories.

At the other extreme are companies who report no particular difficulties with DOE contracts. These tend to be aerospace firms or smaller, high-technology companies that are accustomed to government contract work. An aerospace firm says:

- The general approach of DOE is good. The company has a long-standing list of government (energy-related) programs and has a good working relationship with DOE.

A small high-technology company, very actively engaged in R & D, says:

- We are not large enough to push all of our own product ideas and we need DOE funding. We therefore negotiate to strike a balance between giving away and keeping proprietary know-how.

Much of the aversion to working with DOE can be attributed to companies' appraisal of the contracting process itself, which includes considerations of patent rights and proprietary knowledge security. Some companies, unlike aerospace firms, for example, simply are not accustomed to negotiating government contracts. Some others claim that DOE does not have reasonable patent policies, unlike other agencies such as DOD. In addition to these more critical constraints, there are many complaints concerning the length of time required to negotiate contracts with DOE. Of course, very often the length of time and frequency of delays is closely related to the inherent difficulties with patent and proprietary rights in a prospective contract. Some examples from the interview reports follow:

- DOE patent policy is totally unacceptable to us. We are financing our coal gasification research solely with private money in order to protect proprietary knowledge in ----* technology. Our corporate policy is to engage in joint programs with DOE only where we can protect proprietary know-how. This is our only means of protection from competitors.

- We have a policy of avoiding all government contracts except small supply contracts.

- Patent rights resulting from this (high energy battery) program were very important to the company and critical to the agreement. The final outcome was satisfactory to the company but required one and a half years of negotiations.

- Requests for cost sharing in many cases are not consistent with the state of a given development. A recent example is MHD, a program at least 15 to 20 years away from any financial return. Yet, DOE proposed to auction it off to the organization doing the most cost-sharing. It is in the best interests of the government to encourage and advance longer range, higher risk projects. Where they are trying to accelerate what industry is trying to do, they should carry the major part of the cost. Then, as a program gets closer to commercialization, with prospects of pay-off and with smaller risks, industry should share (more of the cost). The 50-50 cost-sharing programs as demonstrated by DOE are unrealistic and counterproductive.

- Our R & D activities are dependent on our ability to retain proprietary control. For DOE or another government agency to require the company to disclose the composition of chemicals used in oil and gas well treatment, stimulation, and recovery enhancement would severely discourage R & D directed to improving such compositions.

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* Left blank to protect confidentiality.

- Funding should be for more than one year. OMB and Congress are impacting on DOE budgets. Congressional committees are beginning to get into detail on DOE contracts. This is very time consuming.

- It'S difficult to do business with and obtain funding from DOE. There is a need to change contracting practices. There are too many constraints and lack of proprietary rights. Industry is expected to put up money with no real hope of any return. There are no real incentives as projects tend to be in economically soft technologies. DOE insists on fixed price contracts where there is an element of risk and uncertainty.

- DOE seems to operate with the old AEC framework - keeping industry at arms' length, purchasing from them on request... the message to DOE is to simplify contract procedures and somehow provide some incentive for private industry to participate in long-range, high-risk projects.

- During 1978, the company spent considerable time trying to figure out how to enter into contract work with DOE where the company would share costs and end up with new products or new techniques to use in our business. We arranged for a top level aide of DOE to come out and explain DOE procedure to our management but we still have not been able to become involved because of patent restrictions. We are unable to understand how to negotiate and carry out a contract without building a special staff for handling the paperwork.

- We could not get funding in time for a (coal gasification) pilot plant and had to use our own funds. We are now working with temporary emergency operating funds.

- DOE projects...have to be on a cost-sharing basis or on a basis that denies profit from the R & D effort and the recovery of overhead costs. A modified policy along the lines followed by DOD would result in the acceleration of R & D and commercialization.

- We desire to retain proprietary rights. We are willing to pay back to government any amount government put in, under negotiated terms of payment.

- We have not sought government support. As an exception, however, during the past 18 months, we have been trying to obtain approval on a PON for a gasification project. During this time DOE has been reorganized at least three times and each time, the sponsoring party has been changed and as yet the PON has not been issued. We now feel it isn't worth it.

DOE as industry-government intermediary for energy

A substantial number of companies believe that DOE should have more capability, legislated if necessary, to act in an advocacy role when there is an industry-government impasse in the permitting process for specific energy projects and programs. Some companies have explicitly indicated the need for a "one stop" permitting process in which DOE is an interagent between industry and other state, local and federal agencies. The need for DOE to play an industry-government liaison role is especially acute when obstructionist tactics, often duplicative, are employed to block energy developments or when regulations are conflicting or contradictory among various agencies.

Some companies feel that while DOE should be interfacing with Congress in a forceful, positive manner, it is hampered by political considerations and pressures. Often there are two results: sound DOE energy initiatives get defused; capable and talented personnel get discouraged and yield, sometimes by resigning, to their less competent colleagues. Two typical statements in this regard are:

- DOE is watering down its initial ideas because of political pressure (from Congress). We should expect more maturity from Congress.

- Many people in DOE are well qualified and are trying to do a good job but are caught in the middle between Congress and industry, and they have to support the federal end of it... There is not a single Congressman who doesn't pose as an expert on any aspect of energy matters. But we need to get back to the basics in the relationship between DOE and the Conress.

INTERFACE WITH EPA

Although most companies stated their general agreement with the overall environmental goals and objectives of EPA, there is widespread disagreement about the manner in which these goals are to be achieved. In fact, the industry/EPA relationship is considered to be generally adversary.

EPA regulations and numerous requirements for reporting and documentation affect corporate ability to carry on energy-related activities. John Quarles, a former Deputy Administrator of the EPA, accurately desscribes the corporate reaction to EPA, commonly expressed in the interviews:

> The cumulative effect of these requirements is awesome. To a corporate official accustomed to development in the old style, they appear as a benumbing morass of regulatory strictures. He sees himself needing a limitless number of permits imposing strict technical requirements, exposed to the vicissitudes of local political opposition, caught in a crossfire of intergovernmental turf battles, and apt to be done in at the end by new developments in the ever-changing regulatory framework. The result has been cancellation of certain projects important to national energy supply, and delay of many others.* (Emphasis added)

As one company stated:

> Our major concern is the multitudinous array of EPA regulations, which create confusion and uncertainty... Key (energy) programs are now in abeyance until the regulations are clarified.

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* John Quarles, "A Thicket of Environmental Laws," The Wall Street Journal, August 24, 1979.

It is also important to note that when companies make general statements, regarding EPA, they often do not distinguish among federal, state and local EPAs or equivalent agencies.

More specifically, companies perceived the following five problem areas:

Conflict between DOE and EPA objectives.

There is a basic conflict between the objectives of DOE and those of EPA in that energy and environmental policies are established independently.

Diversion of resources to meet EPA standards.

Resources in the form of capital and technical manpower that could be used for energy-related projects must be diverted to meet EPA mandates.

Delays, cancellations and unacceptable return on investment.

Meeting EPA regulations often causes delays or cancellations in energy projects and can reduce the expected return on investment to an unacceptable level.

Lack of cost-benefit assessments.

As they apply to energy, many EPA requirements are unreasonable when evaluated on a cost-benefit basis.

Special problems with coal.

In particular, EPA policies inhibit coal production and utilization which is considered crucial to national energy needs.

It would be difficult if not impossible to rank these statements in order of importance because when companies mention any of them, they almost always assign them an "important" or "very important" rating with respect to their effect on corporate energy strategy, its R & D component, or both.

Also, many companies make reference to the creation of new markets for pollution abatement and control equipment and processes. Indeed, several companies do substantial business in such markets. This is not included in the above list, however, since, from the point of view of the producer of such products, there is no relation to energy.

Each of the problem areas will be discussed below. Examples relating to constraints on coal utilization will be incorporated where appropriate into the disscussion of the four other points. In a comprehensive reading of the interview reports, one cannot fail to be impressed by the preponderance of coal, in all its aspects. Over and over again companies comment on how coal production and utilization are affected by environmental constraints promulgated by EPA. Companies perceive that, in conjunction with nuclear energy, our vast domestic resources of coal must be called upon to solve near and mid-term shortages of energy. In fact, it is likely that coal must also satisfy long-term requirements for portable fuels and chemical feedstocks. Yet, environmental constraints severely affect all the facets of coal production & utilization: from mining operations to ready-now technologies to the most advanced technologies that are far from commercialization. Ready-now technologies requiring only the surmounting of environmental barriers - barriers that industry believes can be surmounted - can not proceed. And in some cases, the most advanced coal combustion technologies, now far from commercialization, have difficulty proceeding even through the R & D stage, because of environmental constraints. When a company states that it had to cancel an important energy project due to environmental problems, that project is very likely a coal-related project. As one company stated:

> We built a waste water treatment system in Puerto Rico and we improved the design and effected changes in waste water treatment in a plant in -----,* all with EPA's cooperation. But we have had problems with EPA wherever and whenever we have attempted to use coal.

Conflict between DOE and EPA objectives

Although few specific examples were proffered, many companies refer to conflicting regulations among government agencies, mainly DOE and EPA. They recognize that DOE and EPA have broad, but distinct, legislated powers to interpret and enforce energy and environmental directives, respectively. The problem companies perceive is that there is little or no coordination between these separate bodies. This frequently results in confusion and uncertainty, delays and outright cancellations of projects, and competition for scarce resources to meet conflicting objectives. The obvious and frequently cited example of such contradictory policies is the DOE mandated

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* Left blank to protect confidentiality.

conversion from oil and gas to coal in utilities and new industrial plants, at the same time EPA required new, more stringent air quality standards which made such conversion impracticable. Indeed, where not prohibited, conversions have been made from coal to oil because compliance with EPA restrictions could not be achieved.

There seems to be a pervasive belief among the interviewed executives that in the conflict between energy and environmental objectives, more often than not, the environmental ones will "win out" over the energy ones without due regard to cost-benefit. Concerning this, an interviewee says:

> Environmental objectives are overwhelming energy ones. For example, plant location is determined more by clean air and water considerations than energy costs and availability.

Others say:

- Our energy strategy and energy-related programs have been very responsive to EPA directives and regulations - some feel that we have been over-responsive. In many cases, this responsiveness has subtracted from the bottom line and there are strong pressures to apply the brakes.
- EPA is the singlemost negative influence in this country on energy matters. This country has been built on risk. EPA has gone too far the other way in trying to protect the public. If you are going to burn coal, certain things are going to happen. You can't have an absolutely clean air standard and burn a billion tons of coal a year and still have an industrial economy. EPA is either irresponsible or

> unaware of the facts regarding cause and effects on energy production and utilization -- and particularly the economic facts.

Diversion of resources to meet EPA standards

The diversion of capital and human resources to meet EPA mandates is easily the most often cited aspect of EPA influence on industry. As it impinges on energy, the diversion of resources is both direct and indirect. Capital diverted to environmental considerations is capital that cannot be spent on energy programs. In addition, there are many examples of direct energy-environmental trade-offs, such as pollution abatement equipment which are costly to purchase or produce and which use energy, themselves.

Energy R & D programs are often curtailed because substantial, portions of companies' R & D effort must be devoted to meeting environmental mandates. The diversion of capital and R & D to environmental considerations is especially apparent wherever coal is involved. In a recent public interest advertisement, the Union Carbide Corporation describes well this diversion of capital as it relates to coal and the environment:

> An industrial-scale, coal-fired boiler, complete with its coal yards, unloading facilities and environmental protection equipment costs about five

times more to build than an oil-fired boiler of the same scale. Union Carbide analyses show that environmental protection costs are typically about 50 percent of the cost of installing a coal-fired boiler.*

A similar statement made by an interviewee was:

> In paper plant installations, EPA coal-fired plant stack gas controls represents over 40% of total expenditures for coal conversion.

Some other examples, illustrating the diversion of resources to EPA mandates, are:

- R & D projects are constantly formulated and guided with attention to environmental considerations. In research on improved energy-related processes the impact of EPA restrictions and requirements play a key role.
- We spent $17 million on pollution abatement in U.S. and Canada.
- Certain effluent disposal problems caused diversion of capital and R & D effort from energy projects. One plant can only run at one-half capacity certain times of the year due to effluent disposal load.
- EPA regulations have not inhibited energy-related R & D activities but have raised the cost of energy to the company.
- Environmental regulatory requirements add more burden to the R & D and technical aspects of a given product or process. An example of the negation of the results of a successful R & D program was EPA action that forced the exclusion of certain materials such as NTA (nitrilo triacetic acid) as a phosphate substitute in detergents.

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* "Can We Have a Cleaner Environment - and Enough Energy?" Source: Energy, Union Carbide Corporation, Box D-20, 270 Park Avenue, New York, New York 10017.

- In the case of liquid sewage, (meeting regulations concerning) flocculation and filtration are costly operations and are energy consuming.

- The main effect (of EPA) is to divert capital and R & D effort without improving our product.

- We have greatly increased the use of coal for boiler fuel but at high capital costs to eliminate pollution.

- EPA regulations are costly and force energy-inefficient programs in the plant. EPA also makes it necessary for the company to develop technology to handle the pollution problems of its customers.

- In an industrial area of importance EPA has established a model for control of sulfur dioxide emissions on a cumulative basis (prevailing winds are West to East). This will restrict industrial boiler users in the eastern sector of the area to premium fuels such as natural gas and distillate fuels. Also, regarding hydrocarbon emission controls, proposed EPA regulations require energy levels of <u>two to three</u> times current usage to incinerate hydrocarbons to meet acceptable levels.

- The tendency has been to make regulatory controls more and more severe and energy-consuming.

- Regulations inhibit other research by diverting technical effort, e.g. analytical work to determine presence of trace materials, developing methods for eliminating benzene.

- Intensive regulation and inspection requires increased cost and demand on time of technical personnel.

- The major problem relates to TVA, which is the largest power producer in the country. TVA has had a running dispute with EPA regarding types of electric equipment to be installed in their fossil fuel plants and has agreed to put very expensive scrubbing equipment in a large number of their plants. The effect will be increased electric costs to everybody in the TVA region -- with significant increase in cost to our plants in TVA territory.

- Excessive delays are costly, particularly those resulting from environmental impact requirements.

- EPA may come out with regulations that will hurt coal business. We have acquired coal deposits with 1% sulfur (under the assumption that 1% is, and would remain, acceptable to EPA). If EPA changes the acceptable sulfur level to 1/2%, this will really hurt.

- Purification of waste water to separate solids and oil requires considerable energy to operate pumps. Also, installation of bag houses in our melt shop to stop dust required the installation of 12 electrically powered fans which cost about one million dollars of electricity per year.

- R & D must find solutions to such problems as how to dispose of sludge resulting from neutralization of sulfuric acid. Can the sludge be roasted or simply buried? These options must be explored and tested.

- Fifteen percent of capital costs are going into environmental control on new plants and new and improved processes rather than additional capacity.

- We are concerned with effluents from new energy saving processes.

- EPA is very important, but in a negative way because its activities are siphoning off capital funds that should be used in a positive way on energy-related matters.

- Restrictions on emissions have forced R & D to reduce emissions in jet engines, stacks, automotive controls, etc.

- There is a tremendous diversion of effort from energy projects. Nine years ago 2% of our R & D effort was devoted to meeting EPA and OSHA standards. Today 40% is going to that effort.

- Unreasonable regulations and the wide variance in individual inspectors' interpretations add to cost.

The above examples are numerous and many similar ones appear in the interview reports. They were often given as statements of fact without accompanying value judgments. If a company reports simply that it spent 15% of its previous year's profits on pollution abatement, this is only "good" or "bad" depending on whether or not that pollution control program has been effectual by some measure of cost-benefit. Often implicit, and sometimes explicit, in such statements, however, was the idea that these programs were mandated arbitrarily without due regard to cost-benefit. This will be discussed below. The point here is that cost-beneficial or not, a dollar spent on pollution control or abatement is generally a dollar that cannot be spent on producing or conserving energy, and it may even be a dollar spent on consuming energy. Respondents often contend that DOE, EPA, and those government entities, who have not acted to coordinated the activities and policies of these federal agencies and their state and local counterparts, do not recognize or consider this simple concept.

Delays, cancellations, and unacceptable return on investment

Many companies report cancellations or delays of important energy projects or programs, including energy R & D, due to EPA restrictions. These cancellations or delays occur either because there is, in their opinion, no plausible way to comply with EPA constraints as they relate to these projects or because the cost associated with compliance is so high as to make reasonable return problematic. An aspect of this problem which stands out when the interview reports are laid end-to-end, so to speak, is that the cancellations, delays, or decisions not to initiate have occurred over the entire range of energy technology. This includes "old" technologies such as coal mining, commercialization of new, energy-related products, R & D never started because of anticipated environmental problems, and postponements of scale-up to the pilot plant stage of advanced coal combustion, gasification, and liquefaction technologies.

Some examples which companies have given are:

- --EPA had a negative influence on a coal gasification project.
- --Two LNG terminals have been blocked by EPA (and other agencies and environmental groups).
- --All this (EPA regulations) impacts on the company's development program and also on the customer's readiness to accept a new system for use in his plant.
- --Environmental regulations have retarded drilling of geothermal wells.
- --Many research projects have been killed by emphasis on environmental considerations.
- --Arbitrarily low limits on atmospheric pollution (50%) inhibit research on attaining reasonable limits.
- --Restrictions on fluid injection have cancelled some of the company's in situ uranium leaching projects.
- --Both state and national EPA standards are restraining to industrial expansion because Western New York state is highly industrialized, and air pollution levels are very high. To bring in new industries requires lowering the pollution control level to the standards that EPA has set. Coal fired installations are a major problem.
- --Many plants cannot expand and company cannot build in three new plant sites which they own.
- --EPA is the major barrier to the burning of wood as a substitute fuel.
- --R & D programs in mining have been suspended until EPA provides commercially acceptable and practical

rules for continued operations, e.g., open pit mining of coal in the Rockies.

--Magneto hydrodynamics emission problems -- have had contacts with EPA re problems of use of coal in MHD.

--EPA has greatly inhibited R & D in both energy and general areas since they have no way of knowing what will be acceptable.

--Key programs are now being held in abeyance until the regulations are clarified. EPA activities affect not only the energy program of the company but the total company operation, including new product development.

--Regulatory activities regarding use of materials in oil well servicing will greatly affect direction and in some instances perhaps effectiveness of R & D.

--Company got out of steel business since they couldn't comply.

--Volatile organic components in paint booths being essentially outlawed. EPA wants them to go to water based paint or high solids paints. Very difficult transition with techniques not available or worked out as yet.

--R & D projects are constantly formulated and guided with attention to environmental considerations. In research on improved energy-related processes, the impact of EPA restrictions and requirements play a key role.

Lack of Cost-Benefit Assessments.

Industry feels that many EPA requirements are unreasonable when evaluated on a cost-benefit basis. Companies claim that EPA established criteria in an aribtrary and undocumented manner and that it does not give due regard to the point at which environmental regulations begin to bear severely diminishing returns. For example, 95% removal of emissions may cost two or three times more than 90% removal, with no demonstrated benefit ensuing from the more stringent criterion.

Another corporate frustration is over EPA's adherence to the "best available technology" criterion, which sets standards that can be achieved technologically but which do not take into consideration that unreasonable additional costs and only marginal benefits may ensue.

Some examples of these points follow:

--Restrictions on the use of manganese anti-knock (MMT) compounds and on the use of leaded gas have cost the company business but they have cost the country even more dearly: 35 to 70 million barrels of crude oil per year due to MMT restrictions alone and significantly greater than 200 million barrels per year due to MMT and lead combined.*

--There is growing concern that EPA regulations represent an overkill. Industry can't continue to carry this burden. EPA should be guided by cost-benefit considerations.

--EPA talks about the "best available technology" but has done a poor job of defining this concept within the framework of the cost-benefit relationship.

--EPA tends to think in terms of best available technology but does not address the matter of realistic economic trade-off nor the human or medical value of control they are considering for application.

--While we do not disagree with EPA's overall goals and aims, some of its regulations are ridiculous. EPA should have to evaluate cost vs. benefit of various degrees of regulation.

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* These statistics may be quite revealing regarding the identity of the company. An authoritative individual within the company has given verbal permission to use them in this report. Also with regard to the use of MMT, it should be noted that EPA has temporarily lifted the ban to alleviate the shortage of lead-free gasoline which occurred during the summer of 1979.

--EPA has misplaced the importance of sulfur in the environment and overemphasized the hazard because it neglected to consider the interactions of sulfur with particulate matter. The utilities are pushed to introduce the best available technology into their operations without demonstrated and documented benefits to the public. EPA must introduce cost-benefit considerations into its regulations.

--There is no such thing as zero risk! We need a balance between benefit vs. cost.

INTERACTION WITH OTHER GOVERNMENT AGENCIES

Throughout the 87 interviews, many comments were made concerning industry/government agency interaction with agencies other than DOE and EPA. In relative terms, however, this commentary was sparse compared to that for DOE and EPA. Furthermore, the relation to energy was not always apparent. Below we shall briefly disscuss each agency with examples from the interviews.

Department of Justice (DOJ)

Most commentary regarding DOJ is concerned with anti-trust actions or threats. Although not arising in Year II interviews, several oil companies mentioned in Year I that threats of divestiture helped to create an adversary atmosphere between government and industry. In addition, one company claims that questionable interpretation and implementation of anti-trust laws have hampered a solar energy project, and a utility company reports anti-trust threats regarding a major electricity generation project and some transmission lines. Several companies (including those interviewed in Year I) feel that strictures on the formation of consortiums unduly hamper large, capital intensive energy projects. Finally, several companies state that rules which prevent coordination and exchange of information among companies on mutual problems often cause duplication and inefficiency which can detrimentally affect energy programs.

Some examples follow:

- --Anti-trust rules prevent coordination on mutual problems. There is a consent decree that requires that various competitors not exchange information. This leads to some duplication and makes it necessary perhaps to use more energy. On the other hand through the government agencies such as EPA and DOT, (our company) is probably getting more information about what its competitors are doing than it did before.

- --A judgment by the Justice Department has virtually immobilized the development of Western Coal. The release of Federal lands for coal leasing in the U.S. has been delayed til 1982. In order to make a viable mining project a minimum acreage is required -- but a patchwork quilt effect by land owners, by the government, railroads, individuals, etc. has stopped coal mine development -- yet Western coal with the lowest sulfur content, is the most desirable for development.

<u>Occupational Health and Safety Administration (OSHA)</u>

Many interviewees rate OSHA impact on corporate energy strategy as "important" or "very important". Most of these describe that impact as diversion of resources away from energy although several state that meeting OSHA mandates often results in greater energy consumption. Some examples follow:

- --From 1969 to 1977 coal mining productivity decreased nearly 50%, most of which was due to regulations imposed by the Federal Mines Health and Safety Act.

- --The main interface (with OSHA) is one of cost and diversion of R & D effort in order to meet OSHA regulations.

--Control of fumes, water, and air discharges affects energy consumption.

--Excessive cost-benefit ratios for restrictions on PVC (poly vinyl chloride) packaging which saves energy over glass or metal packaging. OSHA regulations on exposures exceed safety required for workers.

--OSHA regulation affects plant operation related to energy supplies and production, OSHA has negative impact on energy-intensive R & D.

--With EPA (OSHA is) responsible for diverting 40% of R & D manpower from long range programs. Capital requirements of EPA and OSHA standards slowed improvements needed to save energy.

--Company stopped using ethylene oxide, propylene oxide, and epichlar hydrin since it could not meet standards without excessive capital requirements. Diversion of capital and R & D from energy projects.

--Providing suitable laboratory working conditions to meet OSHA requirements -- both legal and applied -- requires significant changes in building design and equipment, e.g. hood drafts. Both capital expenses and energy costs will be higher.

--The Federal Mining Act of 1969 has cut the productivity and output of our mines tremendously. The way to kill energy in this country is to continue to allow these agencies to work at top speed.

--Noise and ventilation control use more energy and require capital which could be used for other purposes.

Federal Trade Commission (FTC)

There is very little comment in our interview reports regarding FTC impact where energy is concerned. In fact, only two made specific reference to energy considerations:

--New rule making for standards and certification has been published recently in the Federal Register. This may have an energy counterpart.

--Activities relating to LNG have been killed by FTC because of restrictions on terminals. Without terminals, e.g. to store Algerian LNG, we don't get it. The Mexican gas and Canadian gas import opportunities have been seriously inhibited by FTC and other government agencies. We have 600,000 miles of gas pipelines but we need assurance for the future that we will have some gas to go through them.

In addition, one company stated that actions by FTC on competition matters require considerable technical involvement and hence divert such resources from energy.

Department of Defense (DOD)

DOD has relatively little reported impact on companies' energy R & D strategy. More often than not, reference to DOD was in the form of a comparison with DOE. Specifically, several companies when speaking of the difficuly of negotiating contracts with DOE, indicated that DOD was much easier with which to deal and that DOE ought to model its practices on DOD's.

Many of the companies interviewed had substantial contracts with DOD and many of these contracts involve systems which consume energy, and consequently the efficient use of energy must often be considered. One company indicated a direct DOD/energy involvement through a contract investigating synthetic fuels.

Some examples of references to DOD follow:

--Generally, DOD is easier to negotiate contracts than DOE. Practices are more consistent.

--Interactions with the Navy have had positive impact in the area of the Electric-Field Effect.

--(Company) has a number of DOD projects (some related to energy). Example cited was 1.5 kw power source operating on methanol (fuel cell). (Company) has had very good relations with DOD. DOD has a good understanding of how to work with industry, and what it takes to move development from laboratory to production.

--DOD can have an important impact on conservation with its role in promoting conservation through specifying the amount of recyclables that can be used in their products.

--DOD involvement in demonstrations on solar is significant. Work on alternatives to natural oil, e.g. investigation of shale, is an area of interaction of the company with DOD.

--DOD could lead way in solar and other soft sources. Could carry solar generators to field.

Department of Commerce (DOC)

Companies who provided comments on DOC rated its impact on energy strategy and its R & D component as "important" or "not important", i.e. there were no "very important" ratings. Several companies report harmonious working relationships with DOC concerning its voluntary energy conservation reporting system, now evidently a function of DOE. Although only 12 companies commented, there were negative as well as positive comments.

Some examples of interviewee comments concerning DOC follow:

--(The Government) reports to DOC through a trade association on matters relating to energy consumption. This procedure has been a stimulus to seek opportunities for reduction. The aluminum industry, through working with DOC, has made tremendous strides toward lower energy use.

--The patent system is being administered poorly from several points of view. An especially deleterious effect is discouragement of further development or commercialization of novel developments from contracts supported by DOE. On the other side, some patents are not worth the paper they are written on because of lack of back-up by the government to provide protection. In other cases patents are issued without a careful search of the prior art by the Patent Department. The patent examiners aren't doing their homework.

--(We have) high praise for DOC as one government agency that has been an advocate of industry as far as the energy program is concerned. The company works harmoniously with DOC and keeps the agency informed of opportunities relating to government energy programs.

--(DOC) contributed to problems that led to abandonment of _______ coal gasification project.

--Because of imposing a high import tax, DOC has to share the guilt -- along with FTC and DOE (Schlesinger) -- of the lost opportunity to import Mexican gas.

Department of Interior (DOI)

Sixteen companies commented on DOI and rated its effect on corporate energy strategy "important". Most comments involve DOI's land leasing policies. Some examples follow:

--Along with the Justice Department, Interior has been responsible for the quilt pattern of federal lands holding up Western Coal development.

--The department of Interior could do more in assessing resources in various areas and in providing such information to industry. As an example related to energy, estimates of natural geothermal resources or reserves could be quite important.

--Obtaining of permits of various kinds -- e.g. right-of-way permits -- has slowed down commercial installations. On the research side, the company has had beneficial interactions with the U.S. Bureau of Mines -- particularly as related to coal technology.

--Land use management is a very important positive role of DOI. Future forest resources are of key importance to the company.

--Important because DOI has great influence over licensing of oil and gas rights on federal lands and even more so relating to off-shore.

--Interior policies on strip mining of coal need review. Leasing policy has allowed so little to be leased that bidding for leases has gotten out of hand and prices are too high. The end result is a deterrent to needed further coal development.

--Interior policies have major impact on customers, e.g., coal companies. Government policy on leasing government- owned coal reserves is critical. Also policy on surface reclamation of strip mines prevents opening of many surface mines.

--Raw material availability is useful but the government does not use its own data for an early warning system for needed resources. There is a need to clear decisions on the use of federal lands.

--With USGS, DOI controls release of resources on government lands (i.e., coal, uranium, gas, and oil) both on shore and off shore. They could facilitate release of resources and set ground rules for returning areas to acceptable condition and speed up energy production.

--Bureau of Indian Affairs helped block a coal gasification project. Some of the coal is on Navajo lands.

--(DOI affects our corporate energy strategy through the following factors:)
Limitations in access of outer continental shelf for oil exploration and production.
Government-owned lands not being made available for exploration, etc.

Withdrawal of increasing area of public domain from <u>any</u> exploratory operations.

<u>Interstate Commerce Commission (ICC)</u>

Responses from companies regarding ICC focus mostly on its regulatory effect on the transportation of energy, especially coal, and fuel wastage brought about by rules which preclude inter-corporate backhauling by trucks. Companies engaged in commercial trucking say that disallowance of backhauling actually wastes very little fuel, but three companies that maintain their own truck fleets disagree, claiming that a tremendous amount is wasted. <u>One of these companies conservatively estimates that at least 17 million barrels of crude oil per year is wasted across the country in this manner.</u> Some examples of company statements regarding ICC follow:

--Regulation of trucking regarding <u>not</u> allowing back hauling from other company subsidiaries costs the country at least 17 million barrels of oil per year. This would be saved if companies were allowed to haul for their own subsidiaries instead of going home empty as now required. Savings within the company would be large -- 704,000 gallons of diesel fuel per year. Many of company's 203 trucks pass subsidiaries empty on way home.

--We do much of our own internal trucking. ICC regulations prevent us from taking return loads for other companies <u>so trucks go home empty</u>. This wastes tremendous quantities of fuel.

--Our company operates 150 trucks. These waste large amounts of energy since ICC regulations prohibit back hauling except under very limited conditions.

--ICC has done everything they can to impede the movement of coal -- in terms of regulations impacting on slurry pipelines and our railroads. More attention has to be given to our railroad system because you can't barge if you don't have a river.

--Inhibiting actions:
1. Regulatory requirements on interstate transport of well-head gas.
2. Controls relating to who can truck what, and problems of getting licenses etc. -- with impact in terms of trucking costs.

--ICC has posed some problems in terms of coal pricing.

--We are concerned with the status of interstate slurry pipelines for coal transport. Railroads have fought this program by not allowing pipelines to be laid across their right-of-way. Slurry pipelines should be encouraged by ICC with exercise of right of eminent domain the same as oil and gas pipelines.

--Freight rates as influenced by ICC should receive more careful consideration in terms of the cost of coal, wood and waste products. The controlled rates don't reflect the country's needs or the desires of industry and the public.

Internal Revenue Service (IRS)

Eighteen companies commented on IRS impact on corporate and R & D energy strategies. Of these, many gave "very important" ratings. Naturally, IRS rulings can have tremendous impact on companies, but it must be emphasized again that discussion was limited to energy matters. In this regard, most comments on IRS involved tax incentives for R & D, tax credits for conservation, especially as indicated in the National Energy Act, and two companies, one chemical and one oil, specifically mentioned the absence of IRS rulings on capitalization or expensing of chemicals used for enhanced oil recovery. Following are some examples of comments regarding IRS:

--Everytime a law is passed the IRS people try to see how it can be stretched to IRS advantage. They have killed many tax incentives that could have a positive, rather than a negative impact on energy-related capital investment and R & D developments.

--(It is difficult to evaluate IRS impact regarding energy matters.) For example, we are not sure of interpretations of tax incentives relating to other agencies and various elements of the National Energy Act.

--The provisions under NEA providing for tax credits on energy conserving equipment may impact on markets -- definitions important.

--Tax credits for energy saving devices are important. Company is spending about $2 MM this year on energy saving devices.

--Income tax credits relating to energy aspects of the National Energy Act could provide funds for the corporate energy program and R & D projects.

--Tax relief could be important in connection with the National Energy Plan. But broader tax incentives are needed for industry than are provided in the National Energy Act (now very limited and some ill-advised).

--Tax provisions have a direct effect on the corporation's cash flow in various aspects of energy-related projects. Incentives for R & D investment can be influenced by tax provisions in terms of return on investment.

--Changes in tax laws which allow investment tax credits or accelerated depreciation for more energy-efficient devices could impact (two of our subsidiaries) -- could lead to more R & D. Real incentives could spur R & D within (company) to develop more energy-efficient processing and manufacturing equipment, like extruders, mixers, etc.

--Specific tax breaks could be important in providing incentives for certain areas of energy-related R & D.

--A tax incentive for gasohol would be desirable.

--Tax law in the past had been a positive factor in terms of energy credit and in providing incentives for capital investment and R & D projects. Changes in the law reduced their incentives. The recent law changes are now designed to put back what had been taken away.

- --IRS has not ruled as to capitalization or expensing of chemicals used for EOR. This is just one more uncertainty regarding return-on-investment prediction for EOR investments.

- --Expense vs. capitalization of chemicals used for EOR affects economics of recovery. However, a favorable ruling would not provide sufficient incentive to accelerate projects.

Department of Transportation (DOT)

Twenty-six companies provided comments on DOT and of these most rated its impact both on corporate and R & D strategy "very important". Many companies mention DOT mandated auto mileage requirements as affecting both corporate strategy and R & D even when the company is not directly engaged in the manufacture of automotive products. For example, a metals company comments on the decreased use of copper and the increased use of aluminum in automotive radiators. Several companies say that DOT could and should coordinate with other agencies to facilitate and lower the cost of transporting fuels. Several other companies refer to DOT's support of electric car research, especially batteries, as impacting in a very important way on their corporate and R & D strategy. Some examples follow:

- --The DOT regulation of gasoline mileage requirements (is our biggest problem). One third to 40% of our lab work is devoted to trying to meet the 19 MPG requirement. The increasing requirement is non-linear; if it were linear it would save the (auto) industry about $6 billion.

--Mandated mileage requirements have stimulated R & D work and commercialization efforts on a whole line of new and improved energy efficient products (or lighter weight), such as transmissions, air compressors, plastic grills, dashboards, panels, etc., aluminum heat exchangers.

--Two effects on (company) products through pressure by DOT to reduce size and weight of automobiles: 1) lower and lower quantities of copper alloys in radiators; 2) greater use of aluminum.

--Regulations on automotive parts and on plastics have required considerable technical effort.

--Pressure on improved energy efficient autos puts stress on lighter gauge structures.

--Legislated fuel economy standards -- major effect on auto design which affects new and existing chemicals going into fuels -- also plastic raw materials and battery components.

--DOT could work with other agencies, such as Interior, EPA, etc. to facilitate and lower the cost of transporting fuels -- especially coal.

--There is no forward looking, integrated transportation policy in Washington that looks promising with regard to: 1) the transportation of large numbers of people by means other than the automobile, and 2) the transport or mobility of fuels, such as coal, to the energy production facility. There is a lack of continuity by DOT and DOE: we start so many things and they just die. (Here the interviewee describes a major project with DOE involving a vehicle built under DOT contract. Interviewee claims that the vehicle performed well but the project was abandoned). DOT, with DOE, should support new programs and techniques to bring sources, people and plants together including van and share-the-ride pools which seem to have fallen by the wayside.

--Requirement for cathodic protection of gas transmission lines has created some additional expense for (company) not a major concern, however -- a cost and safety factor.

--Interactions between DOT and DOE to promote rail transportation networks and transportation equipment could be extremely important in facilitating movement of the company's basic fuel, and hopefully could reduce a major expense item.

--Permitting process, over-regulation of off shore pipelines (primarily natural gas) makes such pipelines 30-40% more expensive than an oil pipeline built by a company to transport its own oil (latter is not a common carrier). The most expensive over-regulation of all time was the Alaska pipeline, the cost of which was increased 300-400% by regulations.

--DOT could play a more agressive role in promoting navigable waterways for lower transportation costs and improved availability of fuel and raw materials. The rail situation is a disgrace and merits major attention by DOT. DOT publishod an Energy Outlook statement and outlined problems, but action is needed.

--Regulations on shipping are extremely burdensome and costly. For example, when the company ships peroxides overseas:

	Government agency jurisdiction
Product from plant to warehouse and from warehouse to dock	ICC & DOT
Product on the dock	Coast Guard
Product on the ship	Coast Guard & International Shipping Agency

These agencies require different sets of labels, different spacing of piles of freight and they apparently do not talk to each other. When these products are shipped by air there are still different requirements. This applies to all chemical companies. There should be a single prime agency which is assigned responsibility for coordination of the various jurisdictions.

--More attention is needed by DOT to focus on transportation technology to lower cost of fuels and raw materials.

--Freight rates are an important factor in the shipment of waste wood products. High freight costs inhibit improved boiler design for use of such products to cut down on fossil fuel consumption.

--DOT should encourage increased electrification of rail transportation, e.g. through tax incentives. This would involve coal for electric generation of electricity to save oil for other uses.

--Lacking at this time, and much needed, is encouragement of railway piggy-back for trucks. We have allowed our national rail system to deteriorate sadly, yet government subsidy sustains the highway system, puts more trucks on the road, and penalizes the railways by requiring them to maintain their own right-of-ways. Suggestion: Nationalize the rail system -- make it a national resource and subsidize it just as we do airports and highways. Encouraging piggy-back would make a great difference in energy requirements related to transportation.

--DOT funding of electrical vehicle development. Commercialization will create large market for lead and zinc in batteries.

--DOT is interested in the rotary engine work and has provided a stimulus to R & D.

--Electric car work (contract with DOT). Main concern has been batteries. Electric power for car is marginal at present. Have been used fairly successfully by Post Office Department. Use of electric cars would help demand profile for utilities, i.e., charge batteries during off hours.

Federal Drug Administration (FDA)

Only two companies commented on a direct energy relationship with FDA, although an additional few mention the diversion of capital and technical resources caused by FDA regulations. One company says that the preclusion of freon in aerosol sterilization products, which caused a change to radiation sterilization, resulted in a lower cost, energy saving procedure. The savings are not sufficient to recoup the capital expenditures, however. Another company says that FDA requirements regarding the removal of benzene from polystyrene cups is very critical to the future of its business and a substitute material could be more energy intensive.

Toxic Substances Control Act (TOSCA)*

Comments regarding TOSCA are similar to those for EPA, particularly in the sense that complex testing and reporting procedures divert capital and technical, especially R & D, resources away from energy considerations. Besides this type of diversion, many companies agree that TOSCA mandates are causing and will cause fundamental, extremely costly, changes in industrial chemistry and chemical processes. Introduction of many new chemicals in many areas of application, including energy, will be delayed or not introduced at all. Some examples of interviewee comments with respect to TOSCA are:

--Excessive testing leads to delays in marketing of new products. Diversion of effort which could be applied to new products, new processes and other work which could reduce energy consumption for company and for consumers.

--Registration, tests, and reporting use large amounts of technical personnel time. The cost, company wide, is in the millions of dollars. While some of this is essential, there should be a more reasonable overall approach.

--TOSCA puts restraints on anything new and will affect dramatically what the R & D organization can do as regards "hard" chemistry and will throw a number of processes out. The cost of testing a number of new

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* Although administered by EPA, TOSCA was given a separate heading in the Interview Guide.

processes will be enormous, and the front-end cost of testing new specialty products will also be very high. The entire R & D planning process has had a dramatic shaking up. The chemistry has to be considered all the way from the bench to the market place. The impact is overwhelming. By way of contrast, a company using the same catalysts and the same intermediates in Europe has no such problems. The US companies can no longer compete. The absoluteness imposed by TOSCA is simply frightening and the regulatory maze imposed by TOSCA has killed the chemical industry in the United States.

--TOSCA has retarded the introduction of new chemicals due to testing requirements. The barriers to the introduction of new chemicals have taken a quantum increase. This will reduce dramatically the development of new energy saving products due to the need to defend existing products. The impact is so great it cannot be estimated.

--Could effect the future strategy of the SRC project. There are various liquid, gaseous and solid streams from this process -- some more toxic than others. There will be fly ash sludge, waste sludge from scrubbers, and filter residues.

--Although now an unknown factor, the impact of TOSCA could become "very important". Questions are now being raised about the hazardous nature of coal residues. If rated as hazardous substances, the disposal costs of coal ash and spent dolomite could put a real crimp in coal utilization. (Two companies made this comment.)

--New lead standards will probably cause corporation to stop using lead. Battery production will be automated to get people out of labs.

--TOSCA will slow and add costs for developing, producing, and selling new chemicals for enhanced oil recovery.

--A substitute for asbestos in brake linings is likely to have a higher energy component. Materials used today have survived the test economics but now substitutes will need to be found. It is unlikely that they will be as efficient both as to cost and as to their energy component.

--PCB content ruling (polychlorinated biphenyl) in paperboards has a direct effect on recycling materials and a direct impact on energy consumption in the industry.

State, Regional, and Local Agencies

Most companies rate state, regional, and local agencies, particularly state agencies, as having an "important" or "very important" effect on corporate energy strategy and its R & D component. While a few interviewees simply say that these agencies follow federal, especially EPA, directives and guidance, many more say that some states and cities are more stringent than the federal government, particularly with respect to the energy-environment interface. Mentioned in this regard are California (several times), New York, New York City, and Chicago. There is some disagreement among companies. For example, one company says it has a very close working relationship with the state (of New York) and particularly with New York State ERDA and that it would prefer less federal interaction with state groups. In contrast, another company says that states lag behind the federal government in their understanding of energy concepts. Several companies say that state, regional and local regulations are often at variance or conflict with one another and/or the federal government, especially with regard to coal utilization and nuclear development. This, of course, is especially difficult for companies with operations in many states.

Several companies indicate that the policies and actions state, regional, and local agencies, impact the energy aspects of commercial installations and operations particularly in regard to siting and size of plants, installation details, and state EPA regulations. State regulations concerning rates for utilities are also cited as having a negative effect on corporate and R & D energy strategy.

AREAS FOR DOE EMPHASIS

In this part of the interview, respondents were asked to indicate the degree of importance to their company of DOE support for thirteen broad energy technology categories and to describe the kind of support they would encourage. Although respondents were asked to assess the importance of DOE support of broad energy technology categories to their company, in some instances respondents answered in a more general way.

To avoid prompting responses, interviewers asked respondents to comment on each broad energy technology area within each category. This method assured that issues and concerns would be volunteered by respondents and not prompted by interviewers. However, since all companies did not have to express their opinions on all technology areas, the opinions enumerated below are only representative of those companies who addressed those particular areas.

For the most part, there is consensus among company personnel that, primarily, DOE support should be in the area of basic research in universities, government laboratories, and in industrial R & D settings.* It is felt that DOE should not manufacture hardware or products, or be involved in commercialization when industry has the capacity and technology to do so:

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* Analysis of the responses to a similar question on the mail survey does not generate this same inference.

Government should put research money into products and processes through the pilot plant stage only.

Demonstration and perhaps initial commercial plants may have government financial support, but design and operation should be controlled by industrial operations.

Even within the general consensus that government should support front-end, basic, or exploratory research, there are a variety of opinions. One suggestion is that instead of funding research, government should stimulate industry to do R & D through tax breaks and other economic incentives. However, most companies agree that government support may be necessary for long-range technologies or where costs and risks are extremely high, for example in the development of nuclear power, oil resources, or rail transportation. It is stated that basic and applied research should be done by organizations capable of commercializing the new technology. In fact, a few respondents criticize the funding of government laboratories to carry out research in new technologies which they would not be able to commercialize, and some companies believe that the work in such facilities sometimes duplicates work done in other places.

Company opinions of the role government should play in R & D may be influenced somewhat by their own involvement. One interviewer noted, with respect to one company, that "when research is in the company area, they want no government work in applied areas; when research is in someone else's business, they favor going all the way."

The following table indicates the percentage of the 87 respondent companies which indicated varying degrees of importance of DOE support for basic research, applied research, demonstration plants and commercialization with respect to twelve major energy categories. (The miscellaneous category was omitted here.)

PERCENTAGE OF RESPONDENT COMPANIES VIEWING DOE SUPPORT
AS IMPORTANT FOR 12 ENERGY CATEGORIES

	Basic Research				Applied Research Process Engr. Pilot Plant				Demonstration Plant				Commercialization			
	I	NI	NR	NS	I	NI	NR	NS	I	NI	NR	NS	I	NI	NR	NS
Transportation	38	15	28	19	33	13	36	18	20	16	41	23	15	17	38	30
Electric Power Generation	47	14	26	13	37	15	31	17	26	13	37	24	21	15	38	26
Indust Combust & Steam Gen	46	16	24	14	40	13	25	22	32	12	33	23	25	13	37	25
Energy Storage	43	14	33	10	35	16	32	17	24	16	36	24	15	17	42	26
Oil	41	13	36	10	34	14	37	15	30	10	45	15	31	9	40	20
Gas	43	13	34	10	31	14	38	17	26	10	46	18	19	12	46	23
Coal	40	9	31	10	32	10	31	17	37	9	32	22	24	10	38	28
Nuclear	64	10	25	1	59	11	29	1	55	10	32	3	42	14	33	11
Solar & Other Renewables	67	8	18	8	58	8	19	15	41	9	32	18	27	14	33	26
Manuf/Process Changes	22	9	29	40	17	11	29	43	14	10	33	43	10	10	35	45
A/C, Heat Pumps & Heat Rec	25	9	30	36	24	9	32	35	24	9	32	35	19	10	36	35
End Product Efficiency	15	17	33	35	13	18	34	35	10	17	38	35	9	17	39	35
TOTAL	42	12	29	17	35	13	31	21	28	12	36	24	22	13	38	27

I = Important or very important
NI = Not important
NR = No response
NS = DOE should <u>not</u> support activity.

The consensus mentioned above is confirmed by the table which indicates that DOE support is seen as most important for basic research in all twelve categories, then for applied research, process engineering or pilot plants, then, in every category except coal, for demonstration plants, and least important for commercialization.

In the following section the main points which respondents made with respect to the thirteen broad energy categories are presented.

Transportation

Responding companies feel that improvement of the means of transportation is very important. This includes improvement in automotive engines, chassis and body design for better fuel economy, diesel and internal combustion engine improvements, and the development of electric/hybrid vehicles, particularly acceleration of research on more economical batteries for them. Also the cost of transportation of fuels as well as of company products and pipeline technology needs improvement.

The automotive engine needs major attention to aspects such as use of ceramic parts for high temperature operation, use of plastic and other light weight materials to reduce weight, and other means of improving the efficiency of fuel use. More efficient diesel and other types of internal combustion engines need development. The use of plant waste as a fuel for plant trucks is suggested. Also, work on electronic ignition systems which allow better pollution control is of interest.

For all types of engines, for cars, trucks and airplanes, development of alternate types of fuel should be investigated. However, alternate fuels will not solve the problems of some companies for some time. For example, "Airlines are locked into turbine fuel for the next 20 years at least. The time required to develop, test, and establish a network around the world to store and distribute a new fuel is long."

The electric vehicle is of major interest to several companies. The basic research here has been done, but applied work remains. Of particular merit for DOE support is work on the development of batteries for use in electric vehicles. The current state of development of such batteries is sufficiently advanced to be practical: "Energy density now 12-15 watt hours per pound -- need 50 to 100 for practical vehicles. Cost per KW hour must be reduced from $50 - $60 for lead acid to $25." Thus applied research here is necessary and could benefit from DOE support.

The cost of moving fuels and company products needs reduction. Transportation is a significant component in fuel expense, sometimes amounting to 66% of the cost. Government support is important in improving rail and marine transportation and equipment. It is suggested that DOE undertake a commercial analysis of shipping problems to encourage development of rail cars appropriate for different types of products. The railroads in the United States should run as well as they do in Europe and Japan. Government assistance in commercialization of new railroad technologies is considered more acceptable by company respondents than government involvement in commercialization in many other areas. A need for a national policy for maritime transportation is also suggested, as is research in marine transportation and equipment.

Pipeline technology is an area requiring applied research on technology for shipping products, for handling coal slurry and powdered coal, as well as for liquid products, including hazardous materials.

Companies recommend that major attention be given to means of liquid fuel conservation. For example, DOE should evaluate the effects of federal regulations regarding the weight and length of trucks and "disallowances of 'doubles'" which results in trucks travelling extra miles to avoid some states, thus using extra fuel. An additional fuel conservation item suggested is to emphasize and expand such programs as "Share-the-Ride," and "Van Pooling," and to increase the number of busses on the road and mass transit in general.

Electric Power Generation

Companies suggest that DOE direct its attention to suitable repair of the entire regulatory and control structure of utility companies so that they will be able to meet energy needs and raise capital to build needed facilities. These companies should also be encouraged to develop and utilize new technology, while at the same time an acceptable return on their investments should be allowed. A "most constructive step" could be taken here "through FERC by allowing utilities to have a rate structure which would reward them for investment in new technology." It is also recommended that DOE try to alleviate congressional "roadblocks."

The "permiting process" needs redress to cut down on costly, detrimental delays and red tape in licensing of new plants so that utility companies can work with industrial companies, particularly with respect to cogeneration. One company reports that in order to install a unit to burn oil in a gas turbine generator and use exhaust fans for heating, a filing fee of $60,00 to $85,000 is first required, and then a two year delay is anticipated before a permit is obtained. Also, investment tax credit does not apply to cogeneration. "The company may throw up its hands and say, "the (---) with it," and an energy saving installation will be lost. Another respondent comments that utilities must work 10 years ahead due to permitting delays and other industry only three years ahead to respond to market conditions making cooperation difficult. Regulatory controls are a problem if companies attempt to sell electricity back to the power companies via cogeneration. Still another company reports that cogeneration with a small unit did not provide an acceptable return on investment, but improved development might make cogeneration units affordable in small plants.

Some companies feel that DOE involvement in the generation of electrical power is important: "All electric is an attractive way for the U.S. economy to go." However, concern about government's role was also present particularly with respect to agencies like TVA:

> TVA is spending huge sums on electric power generation in specific areas, but the money is coming out of the pockets of the companies in the TVA region. These are activities that have applications throughout the country for all utilities--private as well as public--and therefore should be funded by DOE and made available to utilities throughout the country rather than to permit TVA to spend money for their own purposes.

Many companies are concerned with the cost of needed electricity and feel DOE should have a role in attempting to reduce such costs and improve the efficiency of transmission and distribution of electric power. Several specific suggestions for DOE support were made:

- electric load dispatching system
- development of ultra high voltage transmission
- DC transmission -- one company has experimented with this (a 1 1/2 million volt system with distance of one mile) and reported good results.

One respondent suggested using more coal in the generation of electricity and doing this at the mouth of the coal mine to reduce shipping problems.

In terms of specific technologies, fluidized bed combustion is seen as one of the more promising for electric power generation, and is considered by several respondents to be almost ready for commercialization. One company is currently utilizing this procedure. A number of interviewees state that a push by DOE is necessary to assist companies to move to commercialization of this process. It is also suggested that DOE provide better support for its own demonstration plant.

Magnetohydrodynamic generation needs government support because of the high cost and the high risk of a large capital expenditure on new technology. However, this technology is not seen as ready for demonstration or commercialization at the present time.

Several companies are interested in the gas turbine combined cycle and in research on fuel cells.

One interviewee points out that the technology for low head hydroelectric is

> "...readily available now. If regulation of streams allowed installation of low head hydroelectric units, and if there was an investment tax credit allowing a fast write-off, companies would probably install such units and conserve important oil."

Concern is expressed that here, as in other areas, DOE should <u>not</u> support projects which constitute "re-inventing the wheel, i.e., electric furnace starters rather than pilot lights. Not necessarily well thought out or conserving."

Industrial Combustion and Steam Generation

Again, cogeneration of steam is seen as an important area for DOE support. In particular, DOE could assist in resolving present and potential legal problems which can arise when industrial companies sell energy to utility companies. "Energy sale to utilities may raise a question of utility type control of the energy selling company," a control which many companies would not tolerate and which would result in no cogeneration of energy.

Some companies are currently experimenting with internal cogeneration. For example, one company has large amounts of 80 degree F effluent which is used to heat greenhouses; another interviewee suggests "generation of electricity with a side arm for waste heat utilization (e.g. building heat)." Work on ways to recover low temperature heat and development of more efficient recuperators needs to be done here. Further extension of cogeneration is promising, but because it is costly, government support is important.

Improved efficiency in generation of electricity is deemed important:

> Electrical generation from present boilers is quite inefficient. Need improvements in efficiency of burning gas, and oil to bring the cost down. Should work on combustion technology on all fuels."
>
> Development of steam via improved systems and

utilizing coal would be of value. Geothermal development could be applied to steam as well as electrical generation.

Use of waste materials (e.g. municipal solid waste, coal mining, and other waste materials) is a promising source of energy. A number of companies suggest special DOE attention to basic and applied research in this area.

Several companies have utilized waste materials for industrial combustion and steam generation. One company has developed a plant which separates combustible from non-combustible garbage material. Another solid municipal recovery facility produces an oil as a by-product and this can be used for industrial combustion and steam generation. Several respondents feel development of a demonstration plant in this area would be of value.

There is also interest in research on atmospheric fluidized beds (possibly funded through or jointly with EPRI), coal/oil slurries (one company reports work on firing barks with coal/oil slurries), and also possibly wood/oil slurry, instrumentation and control in the design of equipment, and improved combustion technology on all fuels.

Demonstration plants and commercial developments of these industrial combustion and steam generation technologies merit government support because they are very costly ventures. It is important to emphasize here, however, that many companies are striving for energy self-sufficiency without direct financial support by government. When these companies speak of government support, they stress economic incentives which enhance the potential for an acceptable return on investment such as tax credits, deferred income tax, accelerated depreciation, and, especially for small companies, loan guarantees. Companies also consider the removal of what they perceive as unjustified, unduly severe, environmental constraints as another indirect means of government support.

Energy Storage

Means of energy storage are important and are seen to merit DOE attention and support. DOE should launch a major program of support for all phases of battery development. Batteries are particularly important for use in electric automobiles, but also as energy storage mechanisms. At least 12 companies express interest in DOE's attention to basic and applied research to help produce a high energy, lower cost, longer lasting battery both for electric vehicles and also for storage of off-peak electricity, or energy produced by solar and photovoltaic processes.

A long-range program for research on hydrogen generation to supplement gas and oil supplies is given second priority. One company has done a great deal of research on using hydrogen in aircraft and concluded that this was not practical, but there is support for more investigation of other uses of hydrogen.

Development of pipelines for transporting hydrogen and means of storing this gas are also important.

Some companies are working on thermal energy storage. One company has developed a molten salt thermal storage and pilot plant. Magnetic storage was also suggested -- super conducting magnets may be utilized for energy storage. More hydro storage technology should be encouraged. Compressed air storage is now commercial in Germany.

Oil

Next to nuclear energy, the greatest support from companies for government assistance in commercialization of energy technology is with respect to the development of oil resources. The major problem in development of oil resources is the large capital outlay required and the need for a reasonable return on investment. Much basic research has been done in this area and much of the technology necessary to increase oil resources is available. However, since oil is so important and the technology is presently so expensive, it is felt that government must work with industry to achieve commercialization of the available technology.

Many of the respondents feel that deregulation of prices, more realistic price ceilings, or putting oil prices on the basis of replacement costs would assist in enhanced production of oil, secondary as well as tertiary oil recovery. If DOE wants to obtain EOR oil it is necessary to "provide the incentives required to obtain such oil." Several companies are interested in development of materials for enchanced oil recovery such as alcohol and polymers and surface active agents.

Assistance with development of demonstration facilities is emphasized for development of heavy oil, tar sands and oil shale. Another recommendation is that basic research in the rubbelization of shale _in situ_ should be supported at greater levels at places such as Laramie, Los Alamos, and Lawrence Livermore Laboratories. Financial incentives to companies expending their resources here would assist in development of heavy oil, tar sands, and oil shale.

Geological assesment techniques and offshore drilling and production techniques may benefit from some DOE assistance but they were also considered to be outside of DOE's domain by companies mentioning these technologies. One respondent did suggest that a "conference on advanced drilling methods worldwide would be useful."

Gas

A reliable cost competitive supply of gas is essential to many industrial concerns. Many oil based operations could be converted to gas. Many interviewees consider that only basic research in this area merits DOE support and that deregulation of prices will lead to expanded development of resources.

A number of companies are interested in geopressure methane. Some research is suggested to establish reserves of this gas, and development of a demonstration facility could benefit from DOE attention.

Enhanced gas recovery shows some promise to increase the supply of fuel. Only a few companies are interested in tight sands or Devonian shale and they tended to feel that government support would be helpful to work in this area.

Coal

Coal is important as an alternate fuel but direct conversion to coal from oil is very expensive. It is recommended that DOE support and encourage all aspects of work on coal gasification and liquefaction, which are seen as important means of providing the portable fuels of the future. High risk and high cost necessitate government assistance here. The large investments required are beyond the resources of many private companies and small companies are at a great disadvantage. (The emphasis on the importance of DOE support in the development of these two processes was also supported by the results of the mail questionnaire where they were rated as second only to nuclear energy.)

Many companies have particular interests in this area, including proprietary interests and development in coal gasification. Basic research on lignite and peat is also suggested as a research focus.

Research on coal uses in supplying chemical feedstocks is also very important, particularly in view of dwindling supplies of petroleum. This, of course, is of special interest to the chemical sector of the sample.

Several respondents mention the use of purification projects for cleaning up coal, removing the sulfur, etc. One company reports an interest in installing a plant for processing coal to clean it up in an isolated location to ship to plants for burning if EPA emission standards could be relaxed sufficiently to make installation of such a plant economical. Again it is suggested that DOE be concerned with regulations -- such as EPA emission standards -- and with regulatory inconsistencies which relate to the production and use of coal.

In terms of environmental concerns, demonstration projects in the area of strip mining reclamation studies are mentioned. Much work in mining has been done in the area of safety, and a few companies have interest in this. However, less has been done to improve productivity.

Nuclear

An urgent need for the future development of nuclear energy was the area of greatest consensus among the companies interviewed.

Nuclear energy is considered the most important and lowest cost source of electrical power both now and for the future. Over and over again interviewees refer to the development and growth of nuclear power as "the key need of our country;" "the only hope of the future;" "the only reasonable alternative to fossil fuels we have." Other countries, including Japan, France, Britain, Russia, Germany, are supporting nuclear technological advancements which the United States will have to purchase if nuclear energy development is not resumed. It was suggested that the government take a NASA approach to nuclear development.

The development of nuclear technology is very risky and the costs are extremely high, so that government support is critical in research and development. However, the payoff is seen as worthwhile as nuclear energy has been demonstrated to be an economic source of electric power. "Chicago with more than 50% nuclear electrical generating capacity has a KWH cost of about half that of other non- or low-nuclear generating locations. Tremendous cost savings." One interviewee reported that his company has "one plant located where most energy comes from nuclear -- cheapest rate the company pays."

Regulations and restrictions hamper progress in the nuclear area. Many restrictions limit some work in this area to government laboratories. Also, the permitting process needs simplification. "Japan can design and build a nuclear plant in four years; the Clinton, Illinois nuclear plant will take twelve years." DOE needs to work towards clarification and resolution of regulatory conflicts.

It is recommended that the breeder reactor be moved toward commercialization immediately. If progress is to ensue, companies urge that attention be paid to the problem of waste material disposal. Available techniques must be researched to decide which provide the best and safest solution:

> The nuclear industry has already come to a grinding halt and will stay there unless the waste disposal problem is solved.

Another comment was:

> There are 90 million gallons of weapons waste to reprocess. Build a unit for this purpose and use the same technology for domestic wastes.

Although not perceived as even near ready for commercialization, basic research in the area of fusion should be given great emphasis; one company even recommends a fusion "APOLLO Project." "DOE should carry the ball in fusion -- as they are mandated to do." The large capital outlay necessary means that government must be involved in further development.

DOE must also be concerned with important safety and environmental problems in this development of nuclear resources and with public education concerning nuclear energy.

Because the cost and availability of uranium will be of major importance in determining the cost of nuclear power, companies recommended that DOE be involved with locating uranium. They also state that DOE should support research on other technological developments in the nuclear area.

Solar and Other Renewables

Development of solar energy is the most controversial area in the study, eliciting the most uncertainty about the ability to generate energy at a reasonably economic cost in the future. This is seen as an area which merits basic research as opposed to premature demonstration projects. Solar development is very important for long term energy needs, but because of the uncertainty and the costs which may be entailed, government supported research would be necessary for industry to undertake R & D efforts.

Not all of the respondents favor research in the solar area wholeheartedly. Some feel that too much attention has been given to solar, possibly for political reasons, at the sacrifice of more immediately available technologies, or those that appear to be more economical. Several interviewees express concern that generation and transmission of solar energy to consumers may not be economically feasible for a very long time. One company reports having installed a solar unit to produce steam but this equipment has not justified the operating cost, even assuming a zero installation cost. Another respondent's negative point of view was reflected in the statement "Can't run a factory on solar -- no way! We would have to pave the whole country with solar cells." A few companies are attempting to use some solar energy to heat plants. However, much research and development is required to determine how and if solar power can be produced at a reasonable cost.

The technologies in the solar area in which there is most interest and for which there is most desire for DOE suport at present are production of energy from biomass and solar photovoltaic. Biomass is seen as an energy source and a raw material feedstock. Production of alcohol and methane from wood, potatoes, and marine growth systems are suggested:

> If all farm waste and wood industry waste were converted to alcohol, (this) would be a very important addition to portable fuel needs. Could run all transportation needs of (the) country.

Use of biomass is also proposed as a means of steam generation and for use in stationary vehicles.

Solar photovoltaics is seen as a possible means of battery recharging but basic research is needed before this will be commercially viable. Basic and applied research on heating and cooling, solar thermal power generation, solar industrial process heat, and geothermal are of great interest to several companies.

A number of companies are working in the area of municipal solid waste; others are interested but not yet acting. Commercial production of methane gas from solid waste has been done by some companies. This is considered to be an area of considerable potential to the electricity generating industry.

Generation of energy from wind and ocean thermal sources elicit conflicting views from the few companies that commented on these technologies. Two respondents were quite negative about ocean thermal with comments such as "ridiculous," and "Stop -- not an economical source of energy." However, other company representatives said that the basic information is available and that DOE need only invest in "applied research and demo units -- companies will commercialize." Similarly, one respondent suggests that the use of wind as an energy source is "getting close" and a second reports his company to be working in this area. Two other respondents see wind as having no potential to provide an economic energy supply.

No company reports any positive involvement with tidal technology. Three respondents report interest in a solar space station satellite. Need for research on several other means of harnessing solar energy is mentioned by one or two companies -- solar cells, passive solar, and solar power tower. Demonstration projects will be needed here before commercialization can be attempted.

Two major problems in this area mentioned a number of times during the interviews are storage of solar energy and the conversion of solar energy into heat or electricity. Several interviewees suggest that a major breakthrough and new inventions are needed to produce faster progress in technology and that provision of improved incentives to inventors might be valuable.

Manufacturing Process Changes

Company interviewees repeatedly express the view that private industry should pursue research and development of technology in manufacturing process changes on its own and that this is not an appropriate area for DOE support.

One area where DOE should support basic research is in universities, industrial and government laboratories, with respect to raw materials, particularly metals. For example, one respondent states:

> Zinc is a high energy process looking for better economics. Lead is a low energy process looking for a cleaner process.

Fiber optics was suggested as a substitute for copper wire in the communications area:

> 1000 times more messages simultaneously than through copper wires. Thus both copper and transmission energy would be conserved.

Another respondent recommends

> A good across-the-board survey should be made for basic information in metallurgy, thus establishing priorities for a continuing program.

There is interest in new and improved energy saving processes. Tax or other incentives are suggested as important encouragements to increase capital expenditures beyond present corporate conservation efforts.

Air Conditioning, Heat Pumps, and Heat Recovery

The major point of agreement in this area is that industrial companies have the technological know-how for research and development and will do whatever work is justified on the basis of economic considerations. This is an area where most companies feel that DOE should not become involved to any great extent, particularly in the area of commercialization. "The market for heat pumps is here...DOE should not be involved beyond basic work." Despite the prevalent concern that DOE not become involved in commercialization, a number of companies feel this area merits further basic and applied research. The greatest interest is in process heat recovery. Several specific areas suggested for DOE's attention are:

- special focus on control of particulates in stack gas effluents

- improved efficiency of recuperators for using waste heat
- recovery of heat value from high temperature exhaust effluents
- recovery of waste heat from fuel cells and burning garbage
- industrial usage of recoverable heat from plant liquid effluent before it goes to the sewer.

It is felt that DOE should encourage improvement in and use of energy saving equipment and processes and again it is suggested that tax credits or other incentives could be beneficial.

End Product Efficiency

This is the area where the company respresentatives feel the least need for DOE support of any kind. Several interviewees suggest a role for DOE here in establishing appropriate regulations and consulting with industry about these. It is also recommended that DOE encourage research in the development of energy efficient materials, appliances, equipment, and buildings and promote the use of such products through tax incentives.

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APPENDIX A

Mail Questionnaires for Years I and II

and

Interview Guide for Year II

Inventory of Energy-Related RD&E Funded in Private Sector

(Form Approved 14 March 1977, O.M.B. No. 38-577004)

IRI/RC-DOE SURVEY

Name of corporation or company (or other institution) ______________________

____

Address ______________________

City ______________________

State ______________________ Zip ______ ______________

Name, address and position title of key contact ______________________

____

Telephone number ______________________

Principal business of company ______________________

Please indicate whether you would like to receive a copy of the final report of this survey. Yes ☐ No ☐

Please indicate preference for final disposition of survey questionnaire. Return ☐ Destroy ☐

All information supplied in the following will be treated as Company Confidential-Proprietary, and will be safeguarded as such by I.R.I. Research Corporation and Rensselaer Polytechnic Institute. Only aggregated data will be supplied to DOE. At the end of the project, data sheets will be returned to the respondents or destroyed and no copies will be retained by the investigators.

Corporation sales for 1976:$ ______________________

(If for fiscal year, please specify period:) ______________________

Annual RD&E expenses of *total* corporation for 1976:

$ ______________________ Calendar ______________ Fiscal ______________

Approximate annual total expenditures *solely from corporate funds* for energy-related RD&E:

$ ______________________

If government funds also were utilized for energy-related RD&E, please enter the annual amount of such funds:

$ ______________________

CONFIDENTIAL

CONFIDENTIAL

Please enter in appropriate box below data pertinent to company's RD&E activities funded solely with company and/or corporation money.

Energy Category	Has company done RD&E in area in 1976 — Yes	Has company done RD&E in area in 1976 — No	If yes, approximate spending for 1976	Estimated Total market size from 1976 (in 1976 dollars) — Thru 1985	Estimated Total market size from 1976 (in 1976 dollars) — Thru 2000
Residential and Commercial Section					
Reduced building loads	☐	☐	$ ______	$ ______	$ ______
Heat pumps	☐	☐	______	______	______
Photovoltaic	☐	☐	______	______	______
Wind	☐	☐	______	______	______
Other (specify) ______	☐	☐	______	______	______
Industrial Sector					
Waste heat reduction	☐	☐	$ ______	$ ______	$ ______
Waste heat recovery	☐	☐	______	______	______
Conventional coal co-generation	☐	☐	______	______	______
Waste material utilization (e.g. lubes, tires, etc.)	☐	☐	______	______	______
Biomass, fuels and feedstocks	☐	☐	______	______	______
Industrial heat pumps	☐	☐	______	______	______
More efficient process changes	☐	☐	______	______	______
Solar for industrial process heat	☐	☐	______	______	______
Other (specify) ______	☐	☐	______	______	______
Transportation					
Auto efficiency improvements					
a. Engine development	☐	☐	______	______	______
b. Chassis and body	☐	☐	______	______	______
c. Waste heat utilization	☐	☐	______	______	______
d. Other auto (specify)	☐	☐	______	______	______
Aircraft engine and airframe	☐	☐	______	______	______
Electric auto, batteries and components	☐	☐	______	______	______
Pipeline pumping technologies	☐	☐	______	______	______
New hydrocarbon fuels	☐	☐	______	______	______
Other (specify) ______	☐	☐	______	______	______

Inventory of Energy-Related Research, Development, and Engineering (RD&E) Funded in Private Sector

Supplemental Instructions

As we have indicated in the introductory letter, the general purpose of this survey is to determine the investment of private-sector corporate monies in energy-related research. The following comments should aid you in completing the attached survey questionnaire.

1. Dollar amounts requested refer to all corporate monies dedicated to energy RD&E by the total corporation, including all subsidiaries, and should reflect both domestic and foreign energy RD&E. Annual dollar amounts should refer to 1976 (or the fiscal year closest to 1976).

2. We recognize that you may have dedicated corporate funds for energy RD&E that will have no foreseen impact in the market, for example conservation activities in your own manufacturing processes. Where this is the case, you may enter N/A (for "not applicable") under the column heading "**Estimated Total Market Size.**"

3. Naturally we should like to obtain the most accurate information available, but we realize that the requested dollar amount and market size information may have to be estimated. Please do not hesitate to provide such estimates. In fact, an estimate is preferable to non-response.

CONFIDENTIAL

Energy Category	Has company done RD&E in area in 1976		If yes, approximate spending for 1976	Estimated Total market size from 1976 (in 1976 dollars)	
	Yes	No		Thru 1985	Thru 2000
Supply					
Fluidized bed combustion boiler	☐	☐	$	$	$
Coal/oil slurry	☐	☐			
Nuclear reactor for industrial use	☐	☐			
Enhanced oil recovery	☐	☐			
Enhanced gas recovery	☐	☐			
Oil shale	☐	☐			
Hydrothermal/geothermal (electric and direct heat)	☐	☐			
Coal Conversion:					
a. Gasification	☐	☐			
b. Liquefaction	☐	☐			
c. Feedstocks	☐	☐			
Geopressure methane	☐	☐			
Heavy oil	☐	☐			
Tar sands	☐	☐			
Methane from coal seams	☐	☐			
Devonian shale	☐	☐			
Tight sands	☐	☐			
Solar central receiver with storage	☐	☐			
Solar photovoltaic with storage	☐	☐			
Advanced gas turbine/combined cycle	☐	☐			
Other (specify)__________	☐	☐			

In your opinion, what areas of energy RD&E should be emphasized by DOE?

Where areas of mutual interest between your company and DOE are identified, would you be agreeable to IRIRC arranging for DOE personnel to discuss with you how they might coordinate their work with yours or assist you with it?

☐ Yes ☐ No

If you checked "yes" above, please list areas and persons to be contacted (Note: even if you answer "yes" the rest of the data in this questionnaire remains confidential).

Supplemental Instructions

Inventory of Energy-Related Research and Development (R&D) Funded by the Private Sector

The general purpose of this survey is to determine the extent and character of private-sector investment in energy-related research and development. The following comments should aid you in completing the attached survey questionnaire.

1. The terms *research* and *development* are defined in the Financial Accounting Standards Board Statement No. 2. "Accounting for Research and Development Costs." Briefly, research involves discovering new knowledge that may be useful in developing a new product, service, process or technique or in improving an existing product or process. Development involves translating research or other knowledge into an actual plan or design and includes developmental engineering, construction of prototypes, and the operation of pilot plants that are not economically feasible for production. For complete definitions including examples see the above reference.
2. Dollar amounts requested refer to all corporate spending for energy-related R&D, including that of subsidiaries, and should reflect both domestic and foreign R&D. If you do not have consolidated information for the entire corporation, we should appreciate the name and address of the individual who can provide that information for each unconsolidated division or subsidiary. Include your corporation's share of spending for energy-related R&D performed by or jointly with other agencies, including governmental agencies, other corporations, universities, etc.
3. The energy technologies in the questionnaire may be overlapping and may not match your internal R&D terminology. Please feel free to annotate the technologies but report each energy-related R&D dollar only once.
4. If you report spending under the "Other" headings, please specify the technology. If there is more than one technology, list them separately under the "Miscellaneous" heading.
5. Naturally we should like to obtain the most accurate information available, but we realize that the requested dollar amounts may have to be estimated. Do not hesitate to provide such estimates. An estimate is preferable to a non-response.
6. The amount reported for each year under: "Energy-related R&D funded by corporation" (front page of questionnaire) should be the sum of the amounts reported under the specific technologies (inside pages of questionnaire) for the corresponding year. If not, please comment on the differences.
7. An important concern of DOE is the federal role in the support of energy-related R&D. To assist DOE in determining how it should allocate its limited resources, we are requesting that you indicate opposite each technology listed in the questionnaire your opinion, from your company's point of view, of the relative importance of DOE support of that technology. Specifically, within the context of your own company's present and planned R&D program, how important is DOE support of R&D in particular technology areas? Alternatively, you may believe that DOE should not support a given technology at all, not because it lacks importance but for some other reason such as a potential negative effect on your company's R&D status or strategy. While "DOE support" need not be thought of as necessarily accruing to your company, we again ask that you evaluate that support from your company's perspective. Thus, for example, you may regard support of a particular technology as very important with respect to the enhancement of the Nation's future energy supply, but such support may have no importance with respect to your company's R&D. Please feel free to express any additional opinions regarding the effect of DOE R&D funding on your company in the "Comments" section.
8. Whether or not your company does any energy R&D, your response is important. In fact, inferences based on the survey results may be seriously biased if companies do not respond simply because they have no expenditures.

Thank you again for your cooperation.

Inventory of Energy-Related R&D Funded in Private Sector

(Form Approved 14 March 1977, O. M. B. No. 38-577004, Revised August 1978)

IRI/RC-DOE Survey

Name of corporation or company (or other institution)________________

Address________________

City________________

State________________ ZIP________________

Name, address and position title of key contact________________

____

Telephone number________________

Principal business of company________________

All information supplied in the following will be treated as Company Confidential-Proprietary, and will be safeguarded as such by I.R.I. Research Corporation and Rensselaer Polytechnic Institute. Only aggregated data will be supplied to DOE. At the end of the project, data sheets will be destroyed and no copies will be retained.

	Actual 1976*	Actual 1977*	Budgeted/ Projected 1978*
Total corporate sales	______	______	______
Total corporate funded R&D	______	______	______
Energy-related R&D funded by your corporation	______	______	______
Energy-related R&D funded by federal government	______	______	______
Energy-related R&D funded by other sources	______	______	______

*If periods reported are not calendar years, please specify fiscal periods________________

____

1. For each of the energy technologies listed below, please indicate by checking the appropriate "Yes" box if your company has done or plans to do energy-related R&D and if so the amounts in 1976, 1977, and budgeted, projected, or otherwise estimated for 1978. To indicate the degree of importance you believe DOE should give in its support of each technology, please check the appropriate column under the "Relative Importance" heading: NS (Should Not Support), NI (Not Important), I (Important), or VI (Very Important). Rows left blank will be interpreted as "No opinion."

Energy Technology	Corporate Spending						Relative Importance			
	Yes	1976 Amount	Yes	1977 Amount	Yes	1978 Projected Amount	NS	NI	I	VI
Manufacturing/Process Changes										
Raw Material Changes	☐		☐		☐		☐	☐	☐	☐
Chemical/Refining Processes	☐		☐		☐		☐	☐	☐	☐
New Energy Saving Processes	☐		☐		☐		☐	☐	☐	☐
Improved Energy Saving Processes	☐		☐		☐		☐	☐	☐	☐
Other (Specify) ______	☐		☐		☐		☐	☐	☐	☐
Air Conditioning, Heat Pumps & Heat Recovery										
Residential Heat Pumps	☐		☐		☐		☐	☐	☐	☐
Industrial Heat Pumps	☐		☐		☐		☐	☐	☐	☐
Process Heat Recovery	☐		☐		☐		☐	☐	☐	☐
Use of Low Pressure Exhaust Steam	☐		☐		☐		☐	☐	☐	☐
Other (Specify) ______	☐		☐		☐		☐	☐	☐	☐
End Product Efficiency										
Consumer Appliances	☐		☐		☐		☐	☐	☐	☐
Manufacturing Equipment	☐		☐		☐		☐	☐	☐	☐
Building Insulation	☐		☐		☐		☐	☐	☐	☐
Energy Efficient Buildings	☐		☐		☐		☐	☐	☐	☐
Other (Specify) ______	☐		☐		☐		☐	☐	☐	☐
Transportation										
Automotive Engine	☐		☐		☐		☐	☐	☐	☐
Automotive Chassis and Body	☐		☐		☐		☐	☐	☐	☐
Electric/Hybrid Vehicles	☐		☐		☐		☐	☐	☐	☐
Other Automotive ______	☐		☐		☐		☐	☐	☐	☐
Rail Transportation/Equipment	☐		☐		☐		☐	☐	☐	☐
Aircraft Engine and Airframe	☐		☐		☐		☐	☐	☐	☐
Pipeline Technologies	☐		☐		☐		☐	☐	☐	☐
Marine Transportation/Equipment	☐		☐		☐		☐	☐	☐	☐
Other (Specify) ______	☐		☐		☐		☐	☐	☐	☐

Energy Technology	Corporate Spending						Relative Importance			
	Yes	1976 Amount	Yes	1977 Amount	Yes	1978 Projected Amount	NS	NI	I	VI
Electric Power Generation										
Gas Turbine Combined Cycle	☐		☐		☐		☐	☐	☐	☐
Fuel Cells	☐		☐		☐		☐	☐	☐	☐
Magnetohydrodynamic Generation	☐		☐		☐		☐	☐	☐	☐
Cryogenic Generators	☐		☐		☐		☐	☐	☐	☐
Transmission and Distribution	☐		☐		☐		☐	☐	☐	☐
Low Head Hydroelectric	☐		☐		☐		☐	☐	☐	☐
Fluidized Beds	☐		☐		☐		☐	☐	☐	☐
Other (Specify)______	☐		☐		☐		☐	☐	☐	☐
Industrial Combustion and Steam Generation										
Cogeneration	☐		☐		☐		☐	☐	☐	☐
Atmospheric Fluidized Bed	☐		☐		☐		☐	☐	☐	☐
Coal/Oil Slurry	☐		☐		☐		☐	☐	☐	☐
Waste Material	☐		☐		☐		☐	☐	☐	☐
Instrumentation and Control	☐		☐		☐		☐	☐	☐	☐
Other (Specify)______	☐		☐		☐		☐	☐	☐	☐
Energy Storage										
Pumped Hydro Storage	☐		☐		☐		☐	☐	☐	☐
Compressed Air Storage	☐		☐		☐		☐	☐	☐	☐
Thermal Energy Storage	☐		☐		☐		☐	☐	☐	☐
Batteries	☐		☐		☐		☐	☐	☐	☐
Hydrogen Generation	☐		☐		☐		☐	☐	☐	☐
Other (Specify)______	☐		☐		☐		☐	☐	☐	☐
Oil										
Secondary Oil Recovery	☐		☐		☐		☐	☐	☐	☐
Tertiary Oil Recovery	☐		☐		☐		☐	☐	☐	☐
Materials for Enhanced Oil Recovery	☐		☐		☐		☐	☐	☐	☐
Heavy Oil	☐		☐		☐		☐	☐	☐	☐
Tar Sands	☐		☐		☐		☐	☐	☐	☐
Oil Shale	☐		☐		☐		☐	☐	☐	☐
Geological Assessment Techniques	☐		☐		☐		☐	☐	☐	☐
Offshore Drilling & Production Techniques	☐		☐		☐		☐	☐	☐	☐
Other (Specify)______	☐		☐		☐		☐	☐	☐	☐
Gas										
Enhanced Gas Recovery	☐		☐		☐		☐	☐	☐	☐
Geopressure Methane	☐		☐		☐		☐	☐	☐	☐
Tight Sands	☐		☐		☐		☐	☐	☐	☐
Devonian Shale	☐		☐		☐		☐	☐	☐	☐
Other (Specify)______	☐		☐		☐		☐	☐	☐	☐

Energy Technology	Corporate Spending						Relative Importance			
	1976		1977		1978 Projected					
	Yes	Amount	Yes	Amount	Yes	Amount	NS	NI	I	VI
Coal										
Preparation	☐		☐		☐		☐	☐	☐	☐
Mining	☐		☐		☐		☐	☐	☐	☐
Gasification	☐		☐		☐		☐	☐	☐	☐
Liquefaction	☐		☐		☐		☐	☐	☐	☐
Chemical Feedstocks	☐		☐		☐		☐	☐	☐	☐
Other (Specify)__________	☐		☐		☐		☐	☐	☐	☐
Nuclear										
Fuel Production	☐		☐		☐		☐	☐	☐	☐
Fuel Separation	☐		☐		☐		☐	☐	☐	☐
Reprocessing	☐		☐		☐		☐	☐	☐	☐
Waste Disposal	☐		☐		☐		☐	☐	☐	☐
Liquid Metal Fast Breeder	☐		☐		☐		☐	☐	☐	☐
Other Breeder__________	☐		☐		☐		☐	☐	☐	☐
Reactor for Industrial Process Use	☐		☐		☐		☐	☐	☐	☐
Light Water Reactors	☐		☐		☐		☐	☐	☐	☐
Other Fission__________	☐		☐		☐		☐	☐	☐	☐
Fusion	☐		☐		☐		☐	☐	☐	☐
Other (Specify)__________	☐		☐		☐		☐	☐	☐	☐
Solar and Other Renewable										
Solar Photovoltaic	☐		☐		☐		☐	☐	☐	☐
Solar Thermal Power Generation	☐		☐		☐		☐	☐	☐	☐
Solar Industrial Process Heat	☐		☐		☐		☐	☐	☐	☐
Heating and Cooling	☐		☐		☐		☐	☐	☐	☐
Biomass	☐		☐		☐		☐	☐	☐	☐
Municipal Solid Waste	☐		☐		☐		☐	☐	☐	☐
Tidal	☐		☐		☐		☐	☐	☐	☐
Ocean Thermal	☐		☐		☐		☐	☐	☐	☐
Geothermal	☐		☐		☐		☐	☐	☐	☐
Wind	☐		☐		☐		☐	☐	☐	☐
Other (Specify)__________	☐		☐		☐		☐	☐	☐	☐
Miscellaneous (Specify)										
__________	☐		☐		☐		☐	☐	☐	☐
__________	☐		☐		☐		☐	☐	☐	☐
__________	☐		☐		☐		☐	☐	☐	☐
__________	☐		☐		☐		☐	☐	☐	☐
__________	☐		☐		☐		☐	☐	☐	☐

Continue on Page 6 if necessary

2. Please indicate your opinion on the current level of government sponsorship for the types of energy-related research listed below:

	Government Sponsorship in the Private Sector			Government Funding of Universities and the National Laboratories		
	Too Little	About Enough	Too Much	Too Little	About Enough	Too Much
Basic Research	☐	☐	☐	☐	☐	☐
Applied Research	☐	☐	☐	☐	☐	☐
Process Engineering	☐	☐	☐	☐	☐	☐
Pilot Plant	☐	☐	☐	☐	☐	☐
Demonstration Plant	☐	☐	☐	☐	☐	☐

3. Would you like IRI/RC to arrange for DOE personnel to discuss with you how they might coordinate their work with yours or assist you with it?

☐ Yes ☐ No

If you checked "yes" above, please list areas and persons to be contacted (Note: even if you answer "yes" the rest of the data in this questionnaire remains confidential).

4. Comments (additional space on next page).

THIS IS A FACSIMILE OF INSTRUCTIONS GIVEN

TO THE INTERVIEWERS TO SUPPLEMENT

DIRECTIONS ON THE INTERVIEW GUIDE ITSELF

SUPPLEMENTAL INSTRUCTIONS FOR INTERVIEW GUIDE

A Study of Energy R&D in the Private Sector

Front Page

Mostly self-explanatory. Data on use of tapes and duration of interview will be interesting statistics to report. Also, following receipt of a completed report, we (RPI) shall issue an acknowledgement to the interviewer, not only to apprise him of receipt but to indicate that, at least at that point in time, we see no difficulties with the report and he may destroy the tapes if they exist.

A space for comments is provided for you to mention any incidental information concerning the structure or circumstances (not the content) of the interview.

Pages 1-11

On the basis of the Year I interviews, we are implicitly assuming that virtually all companies have energy strategies - or at least they perceive themselves to have such. If the need for a definition of strategy arises, you may use: "A comprehensive plan of action formulated with the express purpose of achieving a particular goal or set of goals." What we wish to understand is the structure of these strategies. Specifically, what are their crucial components - conservation, new products, etc. The importance ratings will help us to do this but only if they are properly explained in the commentary. This explanation should describe the major energy concerns of the corporation, major energy-related projects, etc. We should also be able to determine, with respect to a category such as conservation, new products, etc., whether an energy R&D strategy is offensive or defensive. In this section, we do not foresee the need to partition, i.e. to rate projects, concerns, etc. separately, but if absolutely necessary, you may do so.

In addition to the points stressed above, the interviewers will have the following responsibilities, which, for the most part, apply not only here, but throughout:

- There should be an importance rating whenever there is substantive commentary. If a category, e.g. Supply, is not a strategic component, then you may indicate across the page "Not a company concern" or a similar statement. Note that in the sample interview, we indicated NI and "No Comment." However, the statement "Not a company concern" would have been more descriptive of the actual situation.

- When the later question is inadvertently anticipated by a respondent, it will be <u>incumbent on the interviewer</u> to either redirect the response accordingly (e.g. tell the respondent that he will be able to expand that point later) or to record the response, where given, and himself insert it in the appropriate place in the final report. Sometimes, however, a response, perhaps with different emphasis, will be quite appropriate in more than one place. For example, if a major energy substitution such as coal for gas is government mandated, then this may be quite appropriately discussed under conservation strategy. When the same point arises later under "industry - government agency interface", the commentary can be duly abbreviated.

- It is easy for the respondent to lose sight of the fact that he is supposed to be discussing only his own company's strategic concerns. When he says that such-and-such is "very important", it should be within the context of his own company's objectives, business concerns, etc. not the nation's, not some other company or industrial sector, and not his next door neighbor's. This is not to say, however, that his company's business concerns cannot coincide with or be part of the nation's, an entire industry's, etc. He may even use a (documentable) example from outside the scope of his corporation.

• "Quotable quotes" are great! We believe that we can enhance the credibility and the immediacy of our interview summaries by indicating, as we have done to some extent in the past, that we are quoting, in so far as confidentiality will allow, an actual statement made in an interview. Thus, you may use quotation marks to indicate that you are more-or-less quoting a respondent's actual statement and that such statement is particularly expressive of an important point. We don't really think it is necessary to state explicitly to a respondent that we may be doing this for the very fact that we are interviewing him should imply that we shall be reporting, in a non-identifiable manner, the substance of what he actually says.

• There very likely will be no statements made under the "Other" category, pp. 10, 11 of the interview guide. If this is the case, you may omit these pages from your submitted report.

<u>Page 12</u>

Self-explanatory. The NEA (National Energy Act) General Information pamphlet referred to is an unnumbered release from the DOE, Office of Public Affairs, dated November, 1978. You should have received sufficient copies from Mike Card.

<u>Pages 13-16</u>

Much of what we have said previously applies as well to this category of the interview. Here, however, it seems apparent that several quite distinct topics might be discussed under one agency. The need for this separation became especially apparent in the pilot interview, the report of which should be referred to for illustration.

We expect that in most interviews many of the agencies listed in the interview guide will not have significant impact on the corporations' energy concerns, including R&D and commercialization activities. Consequently, once having gotten past

DOE and EPA, this part of the interview should proceed very quickly, as was the case in the pilot interview.

One point cannot be overemphasized - KEEP TO THE TOPIC OF ENERGY! In the pilot interview, the first verbatim response to the general question of industry-agency interface was: "How many days do you have?" Much of the subsequent discussion, however, was completly unrelated to energy.

Pages 18-21

Mostly self-explanatory. Item 7 of the Supplemental Instructions for the mail survey is applicable here, except that we have in the interview question further broken down R&D into Basic Research, Applied Research, etc., and added Commercialization. "DOE support" must necessarily mean, for the most part, financial support of one form or another, although exceptions can be envisaged, e.g. support of a particular piece of legislation. But there are many kinds of financial support and it may be difficult to elicit specific, preferred choices, although it would seem particularly important to do so. Based on past experience, including our pilot interview, respondents feel that financial incentives of any and all kinds are lacking. If this is the case, let's find it out, but if they have specific ideas and preferences let's determine those too.

Page 23

Self-explanatory. However, it may be difficult to separate the two responses since both questions are of the "do you have anything to add category?" We have retained both though because we are interested in whether company management is reading and reacting to our report. You may have to do some separating and reassembling in composing your final report.

Page 24

This space is provided for any further comments you, as interviewer, may want to provide. For example, you may want to list or describe one or more points that were particularly emphasized by the respondents. You may also want to evaluate the interview especially if you have negative comments (an open, frank, and productive interview will be evident from the report). You need not include this page if you do not wish to add your comments.

This page is not in the pilot interview reported because it was added later.

INTERVIEW GUIDE FOR "A STUDY OF R&D IN THE PRIVATE SECTOR", YEAR II

COMPANY NAME
AND LOCATION
OF INTERVIEW: ______________________________

DATE OF INTERVIEW: ______________________________

NAMES AND TITLES OF
COMPANY REPRESENTATIVES
AT INTERVIEW:

1. ______________________________

2. ______________________________

3. ______________________________

NAME OF INTERVIEWER(S):

1. ______________________________
2. ______________________________
3. ______________________________

TAPE RECORDER USED: YES ☐ NO ☐

DURATION OF INTERVIEW: ___ HRS. ___ MIN.

COMMENTS:

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CORPORATE ENERGY STRATEGY AND ITS R&D COMPONENT

We would like to discuss with you the nature and content of your company's energy strategy and its R&D component. Specifically, for each of several strategic categories, we shall ask you to describe your major concerns, plans, and projects and how you rate the importance of each category. The particular categories we wish to discuss are:

(1) Conservation,

(2) Supply,

(3) Production and Transmission, and

(4) New Products.

CONSERVATION

1. Within the context of your total corporate energy strategy, how important is in-house conservation, including new processes or major redesign of existing processes? Not important (NI), important (I), or very important (VI)?

2. Does your corporate energy strategy, with respect to in-house conservation, have an R&D component? If so, how important is it? (NI,I,VI)

PRESENT TO NEAR TERM (THRU 1985)

	IMPORTANCE			COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
	NI	I	VI	
Energy Strategy				
R&D Component				

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CONSERVATION

3. (i) How do these importance ratings change for mid term (1985-2000)?

(ii) How do these importance ratings change for long term (Beyond 2000)?

IMPORTANCE / TIME		NI	I	VI	COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
MID TERM (1985-2000)	Energy Strategy				
	R&D Component				
LONG TERM (Beyond 2000)	Energy Strategy				
	R&D Component				

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SUPPLY

1. Within the context of your total corporate energy strategy, how important are energy supply sources or fuels, chemical feedstocks and other scarce or mandated raw materials or fuels? (NI,I,VI)

2. Does your corporate energy strategy, with respect to supply, have an R&D component? If so, how important is it? (NI,I,VI)

PRESENT TO NEAR TERM (THRU 1985)

	IMPORTANCE			COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
	NI	I	VI	
Energy Strategy				
R&D Component				

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SUPPLY

3. (i) How do these importance ratings change for mid term (1985-2000)?

(ii) How do these importance ratings change for long term (Beyond 2000)?

TIME \ IMPORTANCE		NI	I	VI	COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
MID TERM (1985-2000)	Energy Strategy				
	R&D Component				
LONG TERM (Beyond 2000)	Energy Strategy				
	R&D Component				

ENERGY PRODUCTION & TRANSMISSION

1. Within the context of your total corporate energy strategy, how important are energy production and transmission? (NI,I,VI)

2. Does your corporate energy strategy, with respect to energy production and transmission, have an R&D component? If so, how important is it? (NI,I,VI)

PRESENT TO NEAR TERM (THRU 1985)

	IMPORTANCE			COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
	NI	I	VI	
Energy Strategy				
R&D Component				

CONFIDENTIAL

ENERGY PRODUCTION & TRANSMISSION

3. (i) How do these importance ratings change for mid term (1985-2000)?

(ii) How do these importance ratings change for long term (Beyond 2000)?

IMPORTANCE / TIME		NI	I	VI	COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
MID TERM (1985-2000)	Energy Strategy				
	R&D Component				
LONG TERM (Beyond 2000)	Energy Strategy				
	R&D Component				

NEW PRODUCTS

1. Within the context of your total corporate energy strategy, how important are new products or major redesign of existing products? (NI,I,VI)

2. Does your corporate energy strategy, with respect to new products, have an R&D component? If so, how important is it? (NI,I,VI)

PRESENT TO NEAR TERM (THRU 1985)

	IMPORTANCE			COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
	NI	I	VI	
Energy Strategy				
R&D Component				

CONFIDENTIAL

NEW PRODUCTS

3. (i) How do these importance ratings change for mid term (1985-2000)?

(ii) How do these importance ratings change for long term (Beyond 2000)?

IMPORTANCE / TIME		NI	I	VI	COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
MID TERM (1985-2000)	Energy Strategy				
	R&D Component				
LONG TERM (Beyond 2000)	Energy Strategy				
	R&D Component				

OTHER (Specify)

1. Within the context of your total corporate energy strategy, how important are ____ ____?(NI,I,VI)

2. Does your corporate energy strategy, with respect to____________________, have an R&D component? If so how important is it? (NI,I,VI)

PRESENT TO NEAR TERM (THRU 1985)

	IMPORTANCE			COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
	NI	I	VI	
Energy Strategy				
R&D Component				

OTHER (Specify)

3. (i) How do these importance ratings change for mid term (1985-2000)?

(ii) How do these importance ratings change for long term (Beyond 2000)?

TIME \ IMPORTANCE		NI	I	VI	COMMENTARY: (i) Reason for rating; (ii) Major concerns; (iii) Major projects
MID TERM (1985-2000)	Energy Strategy				
	R&D Component				
LONG TERM (Beyond 2000)	Energy Strategy				
	R&D Component				

Does an individual or group have responsibility for the formulation or administration of your energy strategy? What is the scope of responsibility or authority of this individual or group?

What impact will the new National Energy Act have on your corporate energy strategy and its R&D and commercialization components?

[Interviewer may leave copy of NEA General Information pamphlet.]

INTERFACE WITH GOVERNMENT AGENCIES

Indicate the degree of importance of the influence of various agencies on the energy strategy (i) of your company, and (ii) your R&D in particular.							COMMENTARY: Obtain specific examples of actions or policies of agencies that have facilitated or inhibited energy-related R&D activities or commercialization of new energy technology by your company. What specific ways, from your own company's perspective, can these facilitate or accelerate the R&D - commercialization process with respect to energy producing technology?
AGENCY	COMPANY			R&D			
	NI	I	VI	NI	I	VI	
DOE							
EPA							

INTERFACE WITH GOVERNMENT AGENCIES

Indicate the degree of importance of the influence of various agencies on the <u>energy</u> strategy (i) of your company, and (ii) your R&D in particular.							COMMENTARY: Obtain <u>specific</u> <u>examples</u> of actions or policie of agencies that have facilitated or inhibited energy-relat R&D activities or commercialization of new energy technolog by your company. What specific ways, from your own company perspective, can these facilitate or accelerate the R&D - commercialization process with respect to energy producing technology?
AGENCY	COMPANY			R&D			
	NI	I	VI	NI	I	VI	
JUSTICE							
OSHA							
FTC							
DEFENSE							

INTERFACE WITH GOVERNMENT AGENCIES

Indicate the degree of importance of the influence of various agencies on the energy strategy (i) of your company, and (ii) your R&D in particular.

COMMENTARY: Obtain specific examples of actions or policies of agencies that have facilitated or inhibited energy-related R&D activities or commercialization of new energy technology by your company. What specific ways, from your own company's perspective, can these facilitate or accelerate the R&D - commercialization process with respect to energy producing technology?

AGENCY	COMPANY NI	COMPANY I	COMPANY VI	R&D NI	R&D I	R&D VI	
COMMERCE							
INTERIOR							
ICC							
IRS							

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INTERFACE WITH GOVERNMENT AGENCIES

Indicate the degree of importance of the influence of various agencies on the energy strategy (i) of your company, and (ii) your R&D in particular.

COMMENTARY: Obtain specific examples of actions or policies of agencies that have facilitated or inhibited energy-related R&D activities or commercialization of new energy technology by your company. What specific ways, from your own company's perspective, can these facilitate or accelerate the R&D - commercialization process with respect to energy producing technology?

AGENCY	COMPANY			R&D			
	NI	I	VI	NI	I	VI	
TRANSPORTATION							
FDA & TOSCA							
STATE REGIONAL LOCAL (Specify)							
OTHER (Specify)							

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INTERFACE WITH GOVERNMENT AGENCIES

Indicate the degree of importance of the influence of various agencies on the energy strategy (i) of your company, and (ii) your R&D in particular.

COMMENTARY: Obtain specific examples of actions or policies of agencies that have facilitated or inhibited energy-related R&D activities or commercialization of new energy technology by your company. What specific ways, from your own company's perspective, can these facilitate or accelerate the R&D - commercialization process with respect to energy producing technology?

AGENCY	COMPANY			R&D		
	NI	I	VI	NI	I	VI

AREAS FOR DOE EMPHASIS

For the energy technology areas which we shall name below, indicate the degree of importance to your company for DOE support. Describe the kind of support you have in mind. [Interviewers: subheadings for your information; you need read to interviewees only to supply examples of major category.]

Matrix entries: NS, should not support; NI, I, VI as before.

TYPE OF EFFORT / ENERGY TECHNOLOGY	Basic Research	Applied Research, Process Engineering, Pilot Plant	Demonstration Plant	Commercialization	COMMENTARY: Explain rating. Discuss kind and degree of support, level of DOE participation, and to whom, e.g. universities, national labs.
TRANSPORTATION Automotive Engine Automotive Chassis and Body Electric/Hybrid Vehicles Other Automotive __________ Rail Transportation/Equipment Aircraft Engine and Airframe Pipeline Technologies Marine Transportation/Equipment					
ELECTRIC POWER GENERATION Gas Turbine Combined Cycle Fuel Cells Magnetohydrodynamic Generation Cryogenic Generators Transmission and Distribution Low Head Hydroelectric Fluidized Beds					
INDUSTRIAL COMBUSTION & STEAM GENERATION Cogeneration Atmospheric Fluidized Bed Coal/Oil Slurry Waste Material Instrumentation and Control					

AREAS FOR DOE EMPHASIS

For the energy technology areas which we shall name below, indicate the degree of importance to your company for DOE support. Describe the kind of support you have in mind. [Interviewers: subheadings for your information; you need read to interviewees only to supply examples of major category.]

Matrix entries: NS, should not support; NI, I, VI as before.

TYPE OF EFFORT / ENERGY TECHNOLOGY	Basic Research	Applied Research, Process Engineering, Pilot Plant	Demonstration Plant	Commercialization	COMMENTARY: Explain rating. Discuss kind and degree of support, level of DOE participation, and to whom, e.g. universities, national labs.
ENERGY STORAGE Pumped Hydro Storage Compressed Air Storage Thermal Energy Storage Batteries Hydrogen Generation					
OIL Secondary Oil Recovery Tertiary Oil Recovery Materials for Enhanced Oil Recovery Heavy Oil Tar Sands Oil Shale Geological Assessment Techniques Offshore Drilling & Production Techniques					
GAS Enhanced Gas Recovery Geopressure Methane Tight Sands Devonian Shale					

AREAS FOR DOE EMPHASIS

For the energy technology areas which we shall name below, indicate the degree of importance <u>to your company</u> for DOE support. Describe the kind of support you have in mind. [Interviewers: subheadings for your information; you need read to interviewees only to supply examples of major category.]

Matrix entries: NS, <u>should not support</u>; NI, I, VI as before.

ENERGY TECHNOLOGY \ TYPE OF EFFORT	Basic Research	Applied Research, Process Engineering, Pilot Plant	Demonstration Plant	Commercialization	COMMENTARY: Explain rating. Discuss kind and degree of support, level of DOE participation, and to whom, e.g. universities, national labs.
COAL					
Preparation					
Mining					
Gasification					
Liquefaction					
Chemical Feedstocks					
NUCLEAR					
Fuel Production					
Fuel Separation					
Reprocessing					
Waste Disposal					
Liquid Metal Fast Breeder					
Other Breeder________					
Reactor for Industrial Process Use					
Light Water Reactors					
Other Fission________					
Fusion					
SOLAR & OTHER RENEWABLES					
Solar Photovoltaic					
Solar Thermal Power Generation					
Solar Industrial Process Heat					
Heating and Cooling					
Biomass					
Municipal Solid Waste					
Tidal					
Ocean Thermal					
Geothermal					
Wind					

AREAS FOR DOE EMPHASIS

For the energy technology areas which we shall name below, indicate the degree of importance to your company for DOE support. Describe the kind of support you have in mind. [Interviewers: subheadings for your information; you need read to interviewees only to supply examples of major category.]

Matrix entries: NS, should not support; NI, I, VI as before.

ENERGY TECHNOLOGY \ TYPE OF EFFORT	Basic Research	Applied Research, Process Engineering, Pilot Plant	Demonstration Plant	Commercialization	COMMENTARY: Explain rating. Discuss kind and degree of support, level of DOE participation, and to whom, e.g. universities, national labs.
MANUFACTURING PROCESS CHANGES Raw Material Changes Chemical/Refining Processes New Energy Saving Processes Improved Energy Saving Processes					
A/C, HEAT PUMPS AND HEAT RECOVERY Residential Heat Pumps Industrial Heat Pumps Process Heat Recovery Use of Low Pressure Exhaust Steam					
END PRODUCT EFFICIENCY Consumer Appliances Manufacturing Equipment Building Insulation Energy Efficient Buildings					

AREAS FOR DOE EMPHASIS

For the energy technology areas which we shall name below, indicate the degree of importance to your company for DOE support. Describe the kind of support you have in mind. [Interviewers: subheadings for your information; you need read to interviewees only to supply examples of major category.]

Matrix entries: NS, should not support; NI, I, VI as before.

TYPE OF EFFORT / ENERGY TECHNOLOGY	Basic Research	Applied Research, Process Engineering, Pilot Plant	Demonstration Plant	Commercialization	COMMENTARY: Explain rating. Discuss kind and degree of support, level of DOE participation, and to whom, e.g. universities, national labs.
MISCELLANEOUS (Specify)					
ADDITIONAL SPACE					

FINAL COMMENTS

We have sent you a report of findings based on the first year of our study of energy R&D in the private sector. Do you wish to comment on that report? Do you have anything to add? [See especially pp. iv-vi of report, Major Findings of Interviews.]

When IRI/RC makes its report to DOE policy makers, is there a brief message that pulls together your thoughts about the energy situation that you feel should be heard?

APPENDIX B

Information on Corporate Spending

in Each of 102 Technology Areas

TABLE 1

ENERGY R & D SPENDING IN EACH TECHNOLOGY 1976 - 1978
TECHNOLOGIES WITH ONLY 1 RESPONSE COMBINED TO 'OTHER'
(* indicates positive spending, but less than $50 thousand)

CATEGORY/TECHNOLOGY	TOTAL REPORTED ENERGY R&D SPENDING (IN MILLIONS) 1976	1977	1978	TOTAL FIRMS
MANUFACTURING/PROCESS CHANGES				
RAW MATERIAL CHANGES	8.9	16.9	20	43
CHEMICAL / REFINING PROCESSES	46.1	47.8	61.2	32
NEW ENERGY SAVING PROCESSES	21.9	27.7	36.5	67
IMPROVED ENERGY SAVING PROCESSES	30.3	38.4	48.5	83
OTHER MANUFACTURING/PROCESS CHANGES	0.1	0.2	0.2	4
TOTAL MANUFACTURING/PROCESS CHANGES	107.4	131	166.3	121
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY				
RESIDENTIAL HEAT PUMPS	12.6	15	17	16
INDUSTRIAL HEAT PUMPS	4.1	5.4	5.2	15
PROCESS HEAT RECOVERY	5.4	5	9.5	46
USE OF LOW PRESSURE EXHAUST STEAM	*	*	0.2	11
MISC. RESIDENTIAL HEATING	1.5	1.7	2.2	3
MISC. WASTE HEAT REDUCTION	1.7	0.1	0.2	10
OTHER HEAT RECOVERY SYSTEMS	0.3	0.3	1	4
TOTAL AIR COND.,HEAT PUMPS+RECOVERY	25.7	27.6	34.3	69
END PRODUCT EFFICIENCY				
CONSUMER APPLIANCES	14.4	10.5	11.5	15
MANUFACTURING EQUIPMENT	1.7	2.8	3.4	16
BUILDING INSULATION	3.5	4.2	5.5	19
ENERGY EFFICIENT BUILDINGS	1.7	1.6	2.8	25
BLDGS. ENV. CONTROL SYSTEMS	0.2	0.9	1.4	4
LIGHTING AND ASSOC. EQUIPMENT	0.1	0.1	0.1	2
CHEMICALS AND PLASTICS	2.9	3.4	3.6	3
INSULATING PRODUCTS	0.8	1	1.1	2
COATINGS	0.3	1.3	1.5	3
COMMERCIAL PRODUCTS	0.1	0.5	0.9	3
GENERAL CONSERVATION	1.6	1.6	2.9	7
TOTAL END PRODUCT EFFICIENCY	27.2	27.8	34.6	66

TABLE 1 (Continued)

CATEGORY/TECHNOLOGY	Total Reported Spending (Millions) 1976	1977	1978	TOTAL FIRMS
TRANSPORTATION				
AUTOMOTIVE ENGINE	12.4	13.9	16.4	13
AUTOMOTIVE CHASSIS AND BODY	4.8	5.1	4	15
ELECTRIC / HYBRID VEHICLES	3.6	4.2	5.6	11
OTHER AUTOMOTIVE	1.7	2.1	2.5	3
RAIL TRANSPORTATION/EQUIPMENT	0.9	1.5	1.5	5
AIRCRAFT ENGINE AND AIRFRAME	20.7	22	30.4	8
PIPELINE TECHNOLOGIES	5.3	4.7	4.7	20
MARINE TRANSPORTATION / EQUIPMENT	7.3	9.6	10.4	9
MISC. PARTS AND ACCESSORIES	1.4	4.7	5.8	7
FUELS, LUBRICANTS, AND ADDITIVES	14.6	14.5	16.5	9
OTHER TRANSPORTATION	1.5	1.8	2	1
TOTAL TRANSPORTATION	74.1	83.9	99.7	67
ELECTRIC POWER GENERATION				
GAS TURBINE COMBINED CYCLE	1.5	2.2	4.1	10
FUEL CELLS	4.4	1.8	2.7	11
MAGNETOHYDRODYNAMIC GENERATION	1.1	1	1.2	6
TRANSMISSION AND DISTRIBUTION	23.1	43.6	48.1	20
LOW HEAD HYDROELECTRIC	1	5.8	6.3	3
FLUIDIZED BEDS	0.1	0.4	1.7	9
ENVIRONMENTAL, POLL. ABATEMENT	16.1	41.2	46.5	10
IMPROVED PERFORMANCE	0.5	0.5	0.7	4
OTHER ELECTRIC POWER GENERATION	23	25.5	27.2	8
TOTAL ELECTRIC POWER GENERATION	70.9	122	138.6	49
INDUSTRIAL COMBUSTION AND STEAM GENERATION				
COGENERATION	0.8	0.7	1.2	16
ATMOSPHERIC FLUIDIZED BED	0.8	1.7	1.9	7
COAL / OIL SLURRY	0.9	0.8	2.1	15
WASTE MATERIAL	2.3	1.9	2.3	26
INSTRUMENTATION AND CONTROL	1.2	5.3	6.5	17
POLLUTION CONTROL	0.4	2.6	2.5	3
OTHER COMBUSTION AND STEAM GENERATION	0.2	0.4	0.5	7
TOTAL IND. COMBUSTION + STEAM GEN.	6.6	13.2	16.9	54

TABLE 1 (Continued)

CATEGORY/TECHNOLOGY	Total Reported Spending (Millions)			
	1976	1977	1978	TOTAL FIRMS
ENERGY STORAGE				
PUMPED HYDRO STORAGE	0.2	0.1	0.7	2
COMPRESSED AIR STORAGE	*	0.4	0.5	5
THERMAL ENERGY STORAGE	0.9	0.9	1.2	12
BATTERIES	14	34.2	38.6	16
HYDROGEN GENERATION	1.6	1.2	1.4	4
FLYWHEELS	0.1	0.1	0.1	2
OTHER ENERGY STORAGE	1.1	2.3	2.7	5
TOTAL ENERGY STORAGE	17.9	39.2	45.1	35
OIL				
SECONDARY OIL RECOVERY	12.2	13.5	15.8	20
TERTIARY OIL RECOVERY	16.4	22.2	24.8	17
MATERIALS FOR ENHANCED OIL RECOVERY	3.8	4.4	4.9	18
HEAVY OIL	6.7	8.3	9	13
TAR SANDS	7.3	9.5	13.3	12
OIL SHALE	9.5	6.1	8.2	16
GEOLOGICAL ASSESSMENT TECHNIQUES	39.1	37.1	42.3	11
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	17.5	17.3	19.3	11
REFINERY PROCESS IMPROVEMENT	14.6	16	20.6	4
DRILLING AND PROD. TECHNIQUES	17.2	22.2	28.4	9
OTHER OIL	36.3	7	7.4	6
TOTAL OIL	180.7	163.6	195.1	52
GAS				
ENHANCED GAS RECOVERY	5.3	6.4	[illegible].1	12
GEOPRESSURE METHANE	0.4	*	0.1	4
TIGHT SANDS	1.5	1.8	2	6
DEVONIAN SHALE	1.3	0.5	1.5	5
METHANE FROM COAL SEAMS	1.1	1	1.1	3
GEOPHYSICAL	2.6	2.6	2.7	2
LIQUIFIED NATURAL GAS	0.1	0.2	*	2
DRILLING AND PROD. TECHNIQUES	6.6	10.5	13.1	7
OTHER GAS	0	0.7	0.7	3
TOTAL GAS	18.9	23.7	29.4	25

TABLE 1 (Continued)

CATEGORY/TECHNOLOGY	Total Reported Spending (Millions) 1976	1977	1978	TOTAL FIRMS
COAL				
PREPARATION	3.9	3.6	6.2	22
MINING	9.2	9.3	13	16
GASIFICATION	20	17.2	20.8	36
LIQUEFACTION	13.1	15.5	15.9	28
CHEMICAL FEEDSTOCKS	6.6	2.4	3.3	15
POLL. ABATEMT., CLEANING, WASTE	3.1	4.1	5	7
OTHER COAL	1.3	2.5	3.8	8
TOTAL COAL	57.2	54.6	68	60
NUCLEAR				
FUEL PRODUCTION	2.6	2.8	3.7	7
FUEL SEPARATION	4.5	4.9	5.7	3
REPROCESSING	4.9	5.1	5.8	4
WASTE DISPOSAL	2.6	2.7	3.2	7
LIQUID METAL FAST BREEDER	19.8	19.9	21.8	14
OTHER BREEDER	1.4	1.5	1.7	2
REACTOR FOR INDUSTRIAL PROCESS USE	*	0.1	0.1	4
LIGHT WATER REACTORS	15	22.8	26	7
URANIUM EXPLORATION AND MINING	1.4	2.1	1.9	6
OTHER FISSION	2.2	2.6	3.6	6
FUSION	0.8	1.1	2.1	9
OTHER NUCLEAR	12.7	14.9	17	15
TOTAL NUCLEAR	68.1	80.6	92.7	40
SOLAR AND OTHER RENEWABLE				
SOLAR PHOTOVOLTAIC	3	3.5	5.5	24
SOLAR THERMAL POWER GENERATION	0.6	0.3	0.3	16
SOLAR INDUSTRIAL PROCESS HEAT	0.3	0.6	0.7	17
HEATING AND COOLING	3.3	3.5	3	32
BIOMASS	4.9	5.2	6	30
MUNICIPAL SOLID WASTE	5.2	11.1	12.1	16
OCEAN THERMAL	0.4	0.9	1.2	7
GEOTHERMAL	0.6	1.4	2.7	9
WIND	0.2	0.1	0.2	9
OTHER SOLAR AND RENEWABLE	0.5	0.6	0.8	11
TOTAL SOLAR AND OTHER RENEWABLE	18.9	27.1	32.4	87

TABLE 1 (Continued)

CATEGORY/TECHNOLOGY	Total Reported Spending (Millions) 1976	1977	1978	TOTAL FIRMS
MISCELLANEOUS				
EPRI	23.6	29.8	30.9	9
ELECTRIC LOAD MANAGEMENT	0.1	0.2	0.4	4
RESEARCH DEPT. ADMINISTRATION	0.9	1.2	1.6	2
ENERGY RELATED ENVIRONMENTAL STUDIES	2.5	2.6	4	3
ELECTRIC SYSTEMS PLANNING	1	1.4	1.6	3
MISC. RESEARCH INSTITUTES	4.7	5.7	6.5	5
OTHER MISCELLANEOUS	9.9	14.6	17.7	13
TOTAL MISCELLANEOUS	42.7	55.4	62.7	24

TABLE 2

CROSS-SECTION OF 1976 ENERGY R & D SPENDING
TECHNOLOGIES WITH 1 FIRM REPORTING COMBINED TO 'OTHER'

CATEGORY/TECHNOLOGY	NUMBER OF FIRMS REPORTING ENERGY R+D SPENDING FOR 1976				
	NO AMOUNT REPORTED	LESS THAN 100,000	100,000 TO 500,000	500,000 TO TWO MILLION	OVER TWO MILLION
MANUFACTURING/PROCESS CHANGES					
RAW MATERIAL CHANGES	21	15	6		1
CHEMICAL / REFINING PROCESSES	10	7	6	1	8
NEW ENERGY SAVING PROCESSES	25	25	10	5	2
IMPROVED ENERGY SAVING PROCESSES	20	30	22	6	5
OTHER MANUFACTURING/PROCESS CHANGES	1	2	1		
TOTAL MANUFACTURING/PROCESS CHANGES	31	33	29	16	12
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY					
RESIDENTIAL HEAT PUMPS	5	7	1	2	1
INDUSTRIAL HEAT PUMPS	8	4	1	1	1
PROCESS HEAT RECOVERY	12	24	7	2	1
USE OF LOW PRESSURE EXHAUST STEAM	9	2			
MISC. RESIDENTIAL HEATING	2			1	
MISC. WASTE HEAT REDUCTION	2	5	2	1	
OTHER HEAT RECOVERY SYSTEMS	1	1	2		
TOTAL AIR COND.,HEAT PUMPS+RECOVERY	20	29	13	5	2
END PRODUCT EFFICIENCY					
CONSUMER APPLIANCES	5	5	3		2
MANUFACTURING EQUIPMENT	7	3	5	1	
BUILDING INSULATION	9	8	1		1
ENERGY EFFICIENT BUILDINGS	13	7	4	1	
BLDGS. ENV. CONTROL SYSTEMS	2	1	1		
LIGHTING AND ASSOC. EQUIPMENT	1	1			
CHEMICALS AND PLASTICS	1			1	1
INSULATING PRODUCTS		1		1	
COATINGS	2		1		
COMMERCIAL PRODUCTS	2		1		
GENERAL CONSERVATION	2	3	1	1	
TOTAL END PRODUCT EFFICIENCY	23	19	16	4	4

TABLE 2 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
TRANSPORTATION					
AUTOMOTIVE ENGINE	5	4	1	2	1
AUTOMOTIVE CHASSIS AND BODY	3	5	4	3	
ELECTRIC / HYBRID VEHICLES	4	3	1	3	
OTHER AUTOMOTIVE	1		1	1	
RAIL TRANSPORTATION/EQUIPMENT	3	1		1	
AIRCRAFT ENGINE AND AIRFRAME	4	2		1	1
PIPELINE TECHNOLOGIES	6	6	5	2	1
MARINE TRANSPORTATION / EQUIPMENT	4	1	2	1	1
MISC. PARTS AND ACCESSORIES	4		2	1	
FUELS, LUBRICANTS, AND ADDITIVES	1	1	2	1	4
OTHER TRANSPORTATION				1	
TOTAL TRANSPORTATION	18	16	15	10	8
ELECTRIC POWER GENERATION					
GAS TURBINE COMBINED CYCLE	5	2	2	1	
FUEL CELLS	3	2	3	2	1
MAGNETOHYDRODYNAMIC GENERATION	3	1	1	1	
TRANSMISSION AND DISTRIBUTION	2	4	3	8	3
LOW HEAD HYDROELECTRIC	2			1	
FLUIDIZED BEDS	6	2	1		
ENVIRONMENTAL, POLL. ABATEMENT	4		1	4	1
IMPROVED PERFORMANCE	2		2		
OTHER ELECTRIC POWER GENERATION	3	1	2	1	1
TOTAL ELECTRIC POWER GENERATION	19	5	9	9	7
INDUSTRIAL COMBUSTION AND STEAM GENERATION					
COGENERATION	7	5	4		
ATMOSPHERIC FLUIDIZED BED	2	2	3		
COAL / OIL SLURRY	6	6	3		
WASTE MATERIAL	9	10	7		
INSTRUMENTATION AND CONTROL	11	4	1	1	
POLLUTION CONTROL	1	1	1		
OTHER COMBUSTION AND STEAM GENERATION	3	3	1		
TOTAL IND. COMBUSTION + STEAM GEN.	21	17	13	3	

TABLE 2 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
ENERGY STORAGE					
PUMPED HYDRO STORAGE		1	1		
COMPRESSED AIR STORAGE	3	2			
THERMAL ENERGY STORAGE	7	3	1	1	
BATTERIES	4	1	6	3	2
HYDROGEN GENERATION	2			2	
FLYWHEELS		1	1		
OTHER ENERGY STORAGE	4			1	
TOTAL ENERGY STORAGE	16	6	6	4	3
OIL					
SECONDARY OIL RECOVERY	1	4	6	7	2
TERTIARY OIL RECOVERY	3	2	4	5	3
MATERIALS FOR ENHANCED OIL RECOVERY	5	4	7	2	
HEAVY OIL	1	4	2	5	1
TAR SANDS	2	3	4	2	1
OIL SHALE	3	1	8	2	2
GEOLOGICAL ASSESSMENT TECHNIQUES	1	2	1	2	5
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	3	2	1	2	3
REFINERY PROCESS IMPROVEMENT	1		1	1	1
DRILLING AND PROD. TECHNIQUES	3	1		1	4
OTHER OIL	1		1	1	3
TOTAL OIL	12	9	8	8	15
GAS					
ENHANCED GAS RECOVERY	3	1	4	3	1
GEOPRESSURE METHANE	2	1	1		
TIGHT SANDS	1	1	3	1	
DEVONIAN SHALE	2	1	1	1	
METHANE FROM COAL SEAMS		1	1	1	
GEOPHYSICAL			1		1
LIQUIFIED NATURAL GAS		1	1		
DRILLING AND PROD. TECHNIQUES	3			3	1
OTHER GAS	3				
TOTAL GAS	10	1	5	6	3

TABLE 2 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
COAL					
PREPARATION	12	5	3	1	1
MINING	5	3	4	3	1
GASIFICATION	9	9	9	4	5
LIQUEFACTION	6	6	8	7	1
CHEMICAL FEEDSTOCKS	7	1	3	3	1
POLL. ABATEMT., CLEANING, WASTE	2		4		1
OTHER COAL	4		3	1	
TOTAL COAL	13	13	10	13	11
NUCLEAR					
FUEL PRODUCTION	5		1		1
FUEL SEPARATION	2				1
REPROCESSING	2		1		1
WASTE DISPOSAL	3	2	1		1
LIQUID METAL FAST BREEDER	3		5	5	1
OTHER BREEDER		1		1	
REACTOR FOR INDUSTRIAL PROCESS USE	2	2			
LIGHT WATER REACTORS	2	1	2	1	1
URANIUM EXPLORATION AND MINING	2	1	2	1	
OTHER FISSION	1	2	2	1	
FUSION	5	1	3		
OTHER NUCLEAR	7	3	1	1	3
TOTAL NUCLEAR	17	5	9	5	4
SOLAR AND OTHER RENEWABLE					
SOLAR PHOTOVOLTAIC	12	6	3	3	
SOLAR THERMAL POWER GENERATION	5	8	3		
SOLAR INDUSTRIAL PROCESS HEAT	9	7	1		
HEATING AND COOLING	12	12	5	3	
BIOMASS	16	5	6	2	1
MUNICIPAL SOLID WASTE	11	1	3		1
OCEAN THERMAL	4	1	2		
GEOTHERMAL	4	1	4		
WIND	6	2	1		
OTHER SOLAR AND RENEWABLE	4	4	3		
TOTAL SOLAR AND OTHER RENEWABLE	28	31	17	10	1

TABLE 2 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
MISCELLANEOUS					
EPRI				4	5
ELECTRIC LOAD MANAGEMENT	2	2			
RESEARCH DEPT. ADMINISTRATION			1	1	
ENERGY RELATED ENVIRONMENTAL STUDIES		1		2	
ELECTRIC SYSTEMS PLANNING	2			1	
MISC. RESEARCH INSTITUTES			3	1	1
OTHER MISCELLANEOUS	5	4	2		2
TOTAL MISCELLANEOUS	6	3	2	7	6

TABLE 3

CROSS-SECTION OF 1977 ENERGY R & D SPENDING
TECHNOLOGIES WITH 1 FIRM REPORTING COMBINED TO 'OTHER'

CATEGORY/TECHNOLOGY	NUMBER OF FIRMS REPORTING ENERGY R+D SPENDING FOR 1977				
	NO AMOUNT REPORTED	LESS THAN 100,000	100,000 TO 500,000	500,000 TO TWO MILLION	OVER TWO MILLION
MANUFACTURING/PROCESS CHANGES					
RAW MATERIAL CHANGES	11	19	6	5	2
CHEMICAL / REFINING PROCESSES	5	8	7	4	8
NEW ENERGY SAVING PROCESSES	16	24	19	5	3
IMPROVED ENERGY SAVING PROCESSES	22	30	15	11	5
OTHER MANUFACTURING/PROCESS CHANGES		3	1		
TOTAL MANUFACTURING/PROCESS CHANGES	25	29	35	20	12
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY					
RESIDENTIAL HEAT PUMPS	3	8	1	3	1
INDUSTRIAL HEAT PUMPS	5	6	1	2	1
PROCESS HEAT RECOVERY	17	21	4	4	
USE OF LOW PRESSURE EXHAUST STEAM	7	4			
MISC. RESIDENTIAL HEATING	1	1		1	
MISC. WASTE HEAT REDUCTION	9		1		
OTHER HEAT RECOVERY SYSTEMS	2	1	1		
TOTAL AIR COND.,HEAT PUMPS+RECOVERY	25	28	8	7	1
END PRODUCT EFFICIENCY					
CONSUMER APPLIANCES	1	5	7	1	1
MANUFACTURING EQUIPMENT	4	5	5	2	
BUILDING INSULATION	7	7	4		1
ENERGY EFFICIENT BUILDINGS	6	13	5		
BLDGS. ENV. CONTROL SYSTEMS	2		1	1	
LIGHTING AND ASSOC. EQUIPMENT		2			
CHEMICALS AND PLASTICS	1			1	1
INSULATING PRODUCTS			1	1	
COATINGS	1		1	1	
COMMERCIAL PRODUCTS	1		2		
GENERAL CONSERVATION	4	2		1	
TOTAL END PRODUCT EFFICIENCY	15	21	20	7	3

TABLE 3 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
TRANSPORTATION					
AUTOMOTIVE ENGINE	3	3	4	2	1
AUTOMOTIVE CHASSIS AND BODY	6	2	4	2	1
ELECTRIC / HYBRID VEHICLES	3	3	2	3	
OTHER AUTOMOTIVE	1			2	
RAIL TRANSPORTATION/EQUIPMENT	1	1	2	1	
AIRCRAFT ENGINE AND AIRFRAME	3	2		1	2
PIPELINE TECHNOLOGIES	7	3	6	4	
MARINE TRANSPORTATION / EQUIPMENT	1	1	4	2	1
MISC. PARTS AND ACCESSORIES	1	1	1	4	
FUELS, LUBRICANTS, AND ADDITIVES	2		1	3	3
OTHER TRANSPORTATION				1	
TOTAL TRANSPORTATION	21	9	14	13	10
ELECTRIC POWER GENERATION					
GAS TURBINE COMBINED CYCLE	4	1	3	2	
FUEL CELLS	4	3	3	1	
MAGNETOHYDRODYNAMIC GENERATION	2	2	1	1	
TRANSMISSION AND DISTRIBUTION	1	2	5	7	5
LOW HEAD HYDROELECTRIC	1			1	1
FLUIDIZED BEDS	5	2	2		
ENVIRONMENTAL, POLL. ABATEMENT	2		4	1	3
IMPROVED PERFORMANCE	1		3		
OTHER ELECTRIC POWER GENERATION	2	2		2	2
TOTAL ELECTRIC POWER GENERATION	15	5	9	10	10
INDUSTRIAL COMBUSTION AND STEAM GENERATION					
COGENERATION	8	5	3		
ATMOSPHERIC FLUIDIZED BED	3	2	1	1	
COAL / OIL SLURRY	9	4	2		
WASTE MATERIAL	12	9	4	1	
INSTRUMENTATION AND CONTROL	7	6	2	1	1
POLLUTION CONTROL			2		1
OTHER COMBUSTION AND STEAM GENERATION	3	2	2		
TOTAL IND. COMBUSTION + STEAM GEN.	20	14	16	2	2

TABLE 3 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
ENERGY STORAGE					
PUMPED HYDRO STORAGE		1	1		
COMPRESSED AIR STORAGE	1	3	1		
THERMAL ENERGY STORAGE	5	5	1	1	
BATTERIES	2	1	6	3	4
HYDROGEN GENERATION	1	1	1	1	
FLYWHEELS		2			
OTHER ENERGY STORAGE	1	2		2	
TOTAL ENERGY STORAGE	9	8	9	4	5
OIL					
SECONDARY OIL RECOVERY	6	2	4	6	2
TERTIARY OIL RECOVERY	6	1	1	5	4
MATERIALS FOR ENHANCED OIL RECOVERY	4	6	5	3	
HEAVY OIL	5	2	1	4	1
TAR SANDS	5	1	2	2	2
OIL SHALE	4	3	5	3	1
GEOLOGICAL ASSESSMENT TECHNIQUES	2	2	1	1	5
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	1	1	2	4	3
REFINERY PROCESS IMPROVEMENT	1			1	2
DRILLING AND PROD. TECHNIQUES		2	1	2	4
OTHER OIL	4			1	1
TOTAL OIL	11	15	6	7	13
GAS					
ENHANCED GAS RECOVERY	5	1	2	3	1
GEOPRESSURE METHANE	2	2			
TIGHT SANDS	3	1		2	
DEVONIAN SHALE	2	2	1		
METHANE FROM COAL SEAMS	1	1		1	
GEOPHYSICAL			1		1
LIQUIFIED NATURAL GAS		1	1		
DRILLING AND PROD. TECHNIQUES	1		1	3	2
OTHER GAS	1	1		1	
TOTAL GAS	8	3	4	6	4

TABLE 3 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
COAL					
PREPARATION	4	10	5	3	
MINING	1	3	6	4	2
GASIFICATION	9	12	7	5	3
LIQUEFACTION	8	4	7	7	2
CHEMICAL FEEDSTOCKS	10	1	8	3	
POLL. ABATEMT., CLEANING, WASTE	1		4	1	1
OTHER COAL	1	1	5	1	
TOTAL COAL	12	15	11	13	9
NUCLEAR					
FUEL PRODUCTION	3	1	2		1
FUEL SEPARATION	2				1
REPROCESSING	1	1	1		1
WASTE DISPOSAL	3	1	2		1
LIQUID METAL FAST BREEDER	4	1	4	4	1
OTHER BREEDER	1			1	
REACTOR FOR INDUSTRIAL PROCESS USE	2	1	1		
LIGHT WATER REACTORS	3			2	2
URANIUM EXPLORATION AND MINING	1	2	1	2	
OTHER FISSION	1	2	2	1	
FUSION	2	3	4		
OTHER NUCLEAR	5	4	1	1	4
TOTAL NUCLEAR	12	8	9	5	6
SOLAR AND OTHER RENEWABLE					
SOLAR PHOTOVOLTAIC	12	6	3	3	
SOLAR THERMAL POWER GENERATION	8	7	1		
SOLAR INDUSTRIAL PROCESS HEAT	8	5	4		
HEATING AND COOLING	2	18	11	1	
BIOMASS	6	12	9	3	
MUNICIPAL SOLID WASTE	6	3	5		2
OCEAN THERMAL	2	3	1	1	
GEOTHERMAL	3	2	2	2	
WIND	5	4			
OTHER SOLAR AND RENEWABLE	4	5	2		
TOTAL SOLAR AND OTHER RENEWABLE	21	32	19	13	2

TABLE 3 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
MISCELLANEOUS					
EPRI				4	5
ELECTRIC LOAD MANAGEMENT	1	3			
RESEARCH DEPT. ADMINISTRATION				2	
ENERGY RELATED ENVIRONMENTAL STUDIES	1			2	
ELECTRIC SYSTEMS PLANNING	1		1	1	
MISC. RESEARCH INSTITUTES			3	1	1
OTHER MISCELLANEOUS	1	6	3	1	2
TOTAL MISCELLANEOUS	2	4	4	8	6

TABLE 4 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
TRANSPORTATION					
AUTOMOTIVE ENGINE	2	3	4	3	1
AUTOMOTIVE CHASSIS AND BODY	4	3	5	3	
ELECTRIC / HYBRID VEHICLES	1	4	2	4	
OTHER AUTOMOTIVE	1		1		1
RAIL TRANSPORTATION/EQUIPMENT		1	3	1	
AIRCRAFT ENGINE AND AIRFRAME	1	3			4
PIPELINE TECHNOLOGIES	4	6	8	2	
MARINE TRANSPORTATION / EQUIPMENT	1	2	1	4	1
MISC. PARTS AND ACCESSORIES		2	1	3	1
FUELS, LUBRICANTS, AND ADDITIVES	2		1	3	3
OTHER TRANSPORTATION				1	
TOTAL TRANSPORTATION	14	14	15	11	13
ELECTRIC POWER GENERATION					
GAS TURBINE COMBINED CYCLE	2	1	5	1	1
FUEL CELLS	5	2	2	2	
MAGNETOHYDRODYNAMIC GENERATION	1	3	1	1	
TRANSMISSION AND DISTRIBUTION	1	3	4	7	5
LOW HEAD HYDROELECTRIC		1		1	1
FLUIDIZED BEDS	5	1	2	1	
ENVIRONMENTAL, POLL. ABATEMENT	2	1	2	2	3
IMPROVED PERFORMANCE		1	3		
OTHER ELECTRIC POWER GENERATION	1	2	1	2	2
TOTAL ELECTRIC POWER GENERATION	11	7	11	9	11
INDUSTRIAL COMBUSTION AND STEAM GENERATION					
COGENERATION	7	5	3	1	
ATMOSPHERIC FLUIDIZED BED	1	3	2	1	
COAL / OIL SLURRY	7	4	2	2	
WASTE MATERIAL	9	10	5	2	
INSTRUMENTATION AND CONTROL	3	8	4	1	1
POLLUTION CONTROL			2		1
OTHER COMBUSTION AND STEAM GENERATION		5	2		
TOTAL IND. COMBUSTION + STEAM GEN.	14	20	11	7	2

TABLE 4

CROSS-SECTION OF 1978 ENERGY R & D SPENDING
TECHNOLOGIES WITH 1 FIRM REPORTING COMBINED TO 'OTHER'

CATEGORY/TECHNOLOGY	NUMBER OF FIRMS REPORTING ENERGY R+D SPENDING FOR 1978 NO AMOUNT REPORTED	LESS THAN 100,000	100,000 TO 500,000	500,000 TO TWO MILLION	OVER TWO MILLION
MANUFACTURING/PROCESS CHANGES					
RAW MATERIAL CHANGES	10	18	6	6	3
CHEMICAL / REFINING PROCESSES	1	9	9	2	11
NEW ENERGY SAVING PROCESSES	10	20	25	8	4
IMPROVED ENERGY SAVING PROCESSES	13	31	20	13	6
OTHER MANUFACTURING/PROCESS CHANGES	1	2	1		
TOTAL MANUFACTURING/PROCESS CHANGES	17	29	32	27	16
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY					
RESIDENTIAL HEAT PUMPS	2	7	3	3	1
INDUSTRIAL HEAT PUMPS	5	6	1	2	1
PROCESS HEAT RECOVERY	9	22	10	4	1
USE OF LOW PRESSURE EXHAUST STEAM	2	8	1		
MISC. RESIDENTIAL HEATING	1		1	1	
MISC. WASTE HEAT REDUCTION	9		1		
OTHER HEAT RECOVERY SYSTEMS	1	1	1	1	
TOTAL AIR COND.,HEAT PUMPS+RECOVERY	14	30	17	5	3
END PRODUCT EFFICIENCY					
CONSUMER APPLIANCES	2	5	5	2	1
MANUFACTURING EQUIPMENT	3	3	7	3	
BUILDING INSULATION	3	8	6	1	1
ENERGY EFFICIENT BUILDINGS	4	11	8	2	
BLDGS. ENV. CONTROL SYSTEMS	1	1	1	1	
LIGHTING AND ASSOC. EQUIPMENT	1	1			
CHEMICALS AND PLASTICS		1		1	1
INSULATING PRODUCTS			1	1	
COATINGS	2			1	
COMMERCIAL PRODUCTS	1		1	1	
GENERAL CONSERVATION	3	1	1	2	
TOTAL END PRODUCT EFFICIENCY	11	16	21	15	3

TABLE 4 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
ENERGY STORAGE					
PUMPED HYDRO STORAGE			2		
COMPRESSED AIR STORAGE	3	1	1		
THERMAL ENERGY STORAGE	3	6	2	1	
BATTERIES	1	1	6	3	5
HYDROGEN GENERATION	2		1	1	
FLYWHEELS		2			
OTHER ENERGY STORAGE	1		2	2	
TOTAL ENERGY STORAGE	6	6	13	4	6
OIL					
SECONDARY OIL RECOVERY	6	2	3	6	3
TERTIARY OIL RECOVERY	4	2	2	6	3
MATERIALS FOR ENHANCED OIL RECOVERY	3	5	8	2	
HEAVY OIL	5	1	3	3	1
TAR SANDS	4	2	2	2	2
OIL SHALE	5	2	5	2	2
GEOLOGICAL ASSESSMENT TECHNIQUES	2	2	1	1	5
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	1	2		3	5
REFINERY PROCESS IMPROVEMENT	1			1	2
DRILLING AND PROD. TECHNIQUES		2	1	2	4
OTHER OIL	4			1	1
TOTAL OIL	11	13	6	8	14
GAS					
ENHANCED GAS RECOVERY	5	2		2	3
GEOPRESSURE METHANE	2	2			
TIGHT SANDS	3	1		2	
DEVONIAN SHALE	2	2		1	
METHANE FROM COAL SEAMS	1		1	1	
GEOPHYSICAL			1		1
LIQUIFIED NATURAL GAS	1	1			
DRILLING AND PROD. TECHNIQUES			1	4	2
OTHER GAS		2		1	
TOTAL GAS	6	5	2	7	5

TABLE 4 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over to million
COAL					
PREPARATION	2	9	6	5	
MINING	3	1	4	5	3
GASIFICATION	6	11	10	5	4
LIQUEFACTION	8	3	10	4	3
CHEMICAL FEEDSTOCKS	9	1	3	2	
POLL. ABATEMT., CLEANING, WASTE			5	1	1
OTHER COAL	1	2	3	1	1
TOTAL COAL	11	10	[illegible]	17	11
NUCLEAR					
FUEL PRODUCTION	2		4		1
FUEL SEPARATION	1	1			1
REPROCESSING	2		1		1
WASTE DISPOSAL	2	1	3		1
LIQUID METAL FAST BREEDER	4	1	5	3	1
OTHER BREEDER	1			1	
REACTOR FOR INDUSTRIAL PROCESS USE	2	1	1		
LIGHT WATER REACTORS	2	1	1		3
URANIUM EXPLORATION AND MINING	1	3		2	
OTHER FISSION	2		2	1	1
FUSION		4	3	2	
OTHER NUCLEAR	1	7	1	3	3
TOTAL NUCLEAR	7	10	8	9	6
SOLAR AND OTHER RENEWABLE					
SOLAR PHOTOVOLTAIC	7	9	4	4	
SOLAR THERMAL POWER GENERATION	8	7	1		
SOLAR INDUSTRIAL PROCESS HEAT	6	7	4		
HEATING AND COOLING	4	18	9	1	
BIOMASS	4	12	10	4	
MUNICIPAL SOLID WASTE	4	6	2	2	2
OCEAN THERMAL	2	3	1	1	
GEOTHERMAL	3	1	3	2	
WIND	3	5	1		
OTHER SOLAR AND RENEWABLE	1	6	4		
TOTAL SOLAR AND OTHER RENEWABLE	16	34	19	16	2

TABLE 4 (Continued)

Category/Technology	No Amount Reported	Less than 100,000	100,000 to 500,000	500,000 to two million	Over two million
MISCELLANEOUS					
EPRI			1	3	5
ELECTRIC LOAD MANAGEMENT		3	1		
RESEARCH DEPT. ADMINISTRATION				2	
ENERGY RELATED ENVIRONMENTAL STUDIES	1			1	1
ELECTRIC SYSTEMS PLANNING		1	1	1	
MISC. RESEARCH INSTITUTES			2	2	1
OTHER MISCELLANEOUS	1	6	2	1	3
TOTAL MISCELLANEOUS	1	4	5	6	8

APPENDIX C

Information on Comparative Rates of Energy R&D Spending Among Industrial Sectors

TABLE 5

R&D PROFILE OF THE 37 SECTORS OF ALL COMPANIES INCLUDING THOSE REPORTING ZERO ENERGY R&D -1976
(Dollars in Millions)

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
AEROSPACE	17	8	770	14.8	3.9%	1.9%
AIRLINE	7	4	9	0		
APPLIANCES	12	2	28	4.3	1.5%	15.3%
AUTO: CARS, TRUCKS	8	3	293.1	19.1	1.7%	6.5%
AUTO: PARTS, EQUIP	25	8	68	11.6	1.3%	17.1%
BUILDING MATERIALS	30	11	131.5	12.5	1.2%	9.5%
CHEMICALS	62	36	1363.3	104.4	2.8%	7.7%
COMPUTERS	26	7	93.8	0	7.1%	
CONGLOMERATES	18	8	631.1	4.2	3.0%	.7%
CONSTRUCTION	4	3	13	10.7	.6%	82.4%
CONTAINERS	7	3	46.6	8.3	1.3%	17.8%
DRUGS	27	15	626.4	6.7	5.7%	1.1%
ELECTRICAL	31	14	701.6	134.2	2.6%	19.1%
ELECTRIC POWER	16	14	116.9	106.9	.6%	91.4%
ELECTRONICS	45	24	132.8	18.2	3.7%	13.7%
FOOD, BEVERAGES	57	23	143.6	1.5	.4%	1.1%
FUELS	42	21	478.2	225.4	.5%	47.1%
GENERAL MACHINERY	74	30	183.9	34.2	1.6%	18.6%
INSTRUMENTS	40	16	98.4	3	3.3%	3.0%
LEISURE TIME	17	4	44.8	6.7	2.8%	14.9%
METALS + MINING	31	11	122.5	12.5	.6%	10.2%
MISCELLANEOUS MFG.	61	24	91.9	22.9	1.6%	24.9%
NATURAL GAS	8	3	13.9	13.9	.3%	100.0%
OFFICE EQUIPMENT	11	6	252.5	0.2	4.4%	.1%
OIL SERVICE + SUPPLY	16	5	33.3	31.9	.5%	95.9%
PAPER	21	10	77.1	3.7	.8%	4.7%
PERSONAL + HOME CARE	18	8	176.1	0.4	2.0%	.2%
PUBLISHING, PRINTING	6	1				
RADIO, TV, MOVIES	2	1				
RAILROAD	5	0				
SEMICONDUCTORS	10	2	6	0	6.6%	
SERVICES	17	6	18.5	2.3	.2%	12.6%
TELECOMMUNICATIONS	6	4	1171.9	3.2	13.1%	.3%
TEXTILES, APPAREL	16	9	16.4	1.9	.5%	11.7%
TIRES + RUBBER	13	3	81.7	3.4	1.9%	4.2%
TRANSPORTATION EQUIP	4	2	28.5	0.2	.9%	.7%
TRUCKING	4	2	0	0		
TOTALS	814	351	8055.6	823	1.8%	10.2%

TABLE 6

R&D PROFILE OF THE 37 SECTORS OF ALL COMPANIES
INCLUDING THOSE REPORTING ZERO ENERGY R&D - 1977
(Dollars in Millions)

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
AEROSPACE	17	8	843.3	15.9	3.9%	1.9%
AIRLINE	7	4	0	0		
APPLIANCES	12	2	32.2	0.6	1.4%	2.0%
AUTO: CARS,TRUCKS	8	3	350	29.3	1.9%	8.4%
AUTO:PARTS,EQUIP	25	8	78.2	14.2	1.3%	18.2%
BUILDING MATERIALS	30	11	159.2	15.4	1.2%	9.8%
CHEMICALS	62	36	1495	100.2	2.8%	6.7%
COMPUTERS	26	7	130.5	0	7.1%	
CONGLOMERATES	18	8	729.4	23.1	3.1%	3.2%
CONSTRUCTION	4	3	5.4	0.8	.6%	15.2%
CONTAINERS	7	3	47.5	10.2	1.2%	21.5%
DRUGS	27	15	658.6	0.2	5.4%	
ELECTRICAL	31	14	737.8	174.4	2.4%	23.6%
ELECTRIC POWER	16	14	147.6	142.4	.7%	96.5%
ELECTRONICS	45	24	151	15.6	3.4%	10.3%
FOOD, BEVERAGES	57	23	162.3	1.6	.4%	1.0%
FUELS	42	21	520.8	240.7	.5%	46.2%
GENERAL MACHINERY	74	30	176.4	36.9	1.4%	20.9%
INSTRUMENTS	40	16	115.6	3.2	3.4%	2.8%
LEISURE TIME	17	4	50.2	8	2.8%	15.9%
METALS + MINING	31	11	119.3	19.5	.4%	16.4%
MISCELLANEOUS MFG.	61	24	91.2	26.9	1.3%	29.5%
NATURAL GAS	9	3	10.1	10.1	.2%	100.0%
OFFICE EQUIPMENT	11	6	296.9	0.4	4.5%	.1%
OIL SERVICE + SUPPLY	16	5	38.4	36.7	.5%	95.5%
PAPER	21	10	86	3.3	.9%	3.8%
PERSONAL + HOME CARE	18	8	233.6	0	2.5%	
PUBLISHING,PRINTING	6	1				
RADIO,TV,MOVIES	2	1				
RAILROAD	5	0				
SEMICONDUCTORS	10	2	10.3	0	7.0%	
SERVICES	17	6	19.2	3.3	.2%	17.4%
TELECOMMUNICATIONS	6	4	771.9	3.9	7.5%	.5%
TEXTILES, APPAREL	16	9	16.4	2.1	.4%	12.9%
TIRES + RUBBER	13	3	92.4	4.6	1.9%	5.0%
TRANSPORTATION EQUIP	4	2	36.6	0.9	1.0%	2.5%
TRUCKING	4	2	0	0		
TOTALS	814	351	8412.5	944.8	1.7%	11.2%

TABLE 7

R&D PROFILE OF THE 37 SECTORS OF ALL COMPANIES
INCLUDING THOSE REPORTING ZERO ENERGY R&D - 1978
(Dollars in Millions)

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
AEROSPACE	17	8	1027.8	20.9	4.2%	2.0%
AIRLINE	7	4	3.5	3.5		100.0%
APPLIANCES	12	2	14.7	0.7	.6%	4.9%
AUTO: CARS, TRUCKS	9	3	356.8	41.3	2.4%	11.6%
AUTO: PARTS, EQUIP	25	8	65.3	16.2	1.4%	24.8%
BUILDING MATERIALS	30	11	176.5	17.3	1.2%	9.8%
CHEMICALS	62	36	1603.2	121.3	2.7%	7.6%
COMPUTERS	26	7	189.5	0	7.5%	
CONGLOMERATES	18	8	867.2	28.8	3.7%	3.3%
CONSTRUCTION	4	3	6.3	1.8	.8%	29.0%
CONTAINERS	7	3	48.7	10.9	1.1%	22.4%
DRUGS	27	15	759.3	0.3	5.5%	
ELECTRICAL	31	14	907.9	203.9	2.6%	22.5%
ELECTRIC POWER	16	14	157.2	153	.7%	97.4%
ELECTRONICS	45	24	172.2	21	3.4%	12.2%
FOOD, BEVERAGES	57	23	161.5	1.7	.5%	1.1%
FUELS	42	21	582	290.9	.5%	50.0%
GENERAL MACHINERY	74	30	191.5	42.4	1.3%	22.1%
INSTRUMENTS	40	16	125.9	4.2	3.2%	3.3%
LEISURE TIME	17	4	49.7	8.9	2.5%	18.0%
METALS + MINING	31	11	146	13.4	.6%	9.2%
MISCELLANEOUS MFG.	61	24	99.7	33.5	1.3%	33.6%
NATURAL GAS	8	3	9.4	9.4	.2%	100.0%
OFFICE EQUIPMENT	11	6	332.6	0.7	4.7%	.2%
OIL SERVICE + SUPPLY	16	5	48.3	47.4	.6%	98.1%
PAPER	21	10	97.4	3.9	.9%	4.0%
PERSONAL + HOME CARE	18	8	263.9	0.1	2.5%	
PUBLISHING, PRINTING	6	1				
RADIO, TV, MOVIES	2	1				
RAILROAD	5	0				
SEMICONDUCTORS	10	2	16.8	0	7.4%	
SERVICES	17	6	14.6	3.7	.1%	25.2%
TELECOMMUNICATIONS	6	4	821.3	4.1	35.0%	.5%
TEXTILES, APPAREL	16	9	17.4	2.1	.5%	11.9%
TIRES + RUBBER	13	3	100.7	6.7	1.8%	6.6%
TRANSPORTATION EQUIP	4	2	44.8	0.8	1.1%	1.8%
TRUCKING	4	2	0	0		
TOTALS	914	351	9539.6	1114.7	1.9%	11.7%

TABLE 8

YEAR TO YEAR COMPARISON OF R&D PERCENTAGES FOR THE 37 SECTORS OF ALL COMPANIES INCLUDING THOSE REPORTING ZERO ENERGY R&D

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	1976 R+D/ SALES	1976 ENERGY/ TOTAL R+D	1977 R+D/ SALES	1977 ENERGY/ TOTAL R+D	1978 R+D/ SALES	1978 ENERGY/ TOTAL R+D
AEROSPACE	17	3.9%	1.9%	3.9%	1.9%	4.2%	2.0%
AIRLINE	7						100.0%
APPLIANCES	12	1.5%	15.3%	1.4%	2.0%	.6%	4.9%
AUTO: CARS, TRUCKS	8	1.7%	6.5%	1.9%	8.4%	2.4%	11.6%
AUTO: PARTS, EQUIP	25	1.3%	17.1%	1.3%	18.2%	1.4%	24.8%
BUILDING MATERIALS	30	1.2%	9.5%	1.2%	9.8%	1.2%	9.8%
CHEMICALS	62	2.8%	7.7%	2.8%	6.7%	2.7%	7.6%
COMPUTERS	26	7.1%		7.1%		7.5%	
CONGLOMERATES	18	3.0%	.7%	3.1%	3.2%	3.7%	3.3%
CONSTRUCTION	4	.6%	82.4%	.6%	15.2%	.8%	29.0%
CONTAINERS	7	1.3%	17.8%	1.2%	21.5%	1.1%	22.4%
DRUGS	27	5.7%	1.1%	5.4%		5.5%	
ELECTRICAL	31	2.6%	19.1%	2.4%	23.6%	2.6%	22.5%
ELECTRIC POWER	16	.6%	91.4%	.7%	96.5%	.7%	97.4%
ELECTRONICS	45	3.7%	13.7%	3.4%	10.3%	3.4%	12.2%
FOOD, BEVERAGES	57	.4%	1.1%	.4%	1.0%	.5%	1.1%
FUELS	42	.5%	47.1%	.5%	46.2%	.5%	50.0%
GENERAL MACHINERY	74	1.6%	13.6%	1.4%	20.9%	1.3%	22.1%
INSTRUMENTS	40	3.3%	3.0%	3.4%	2.8%	3.2%	3.3%
LEISURE TIME	17	2.8%	14.9%	2.8%	15.9%	2.5%	18.0%
METALS + MINING	31	.6%	10.2%	.4%	16.4%	.6%	9.2%
MISCELLANEOUS MFG.	61	1.6%	24.9%	1.3%	29.5%	1.3%	33.6%
NATURAL GAS	8	.3%	100.0%	.2%	100.0%	.2%	100.0%
OFFICE EQUIPMENT	11	4.4%	.1%	4.5%	.1%	4.7%	.2%
OIL SERVICE + SUPPLY	16	.5%	95.9%	.5%	95.5%	.6%	98.1%
PAPER	21	.8%	4.7%	.9%	3.8%	.9%	4.0%
PERSONAL + HOME CARE	18	2.0%	.2%	2.5%		2.5%	
PUBLISHING, PRINTING	6						
RADIO, TV, MOVIES	2						
RAILROAD	5						
SEMICONDUCTORS	10	6.6%		7.0%		7.4%	
SERVICES	17	.2%	12.6%	.2%	17.4%	.1%	25.2%
TELECOMMUNICATIONS	6	13.1%	.3%	7.5%	.5%	35.0%	.5%
TEXTILES, APPAREL	16	.5%	11.7%	.4%	12.9%	.5%	11.9%
TIRES + RUBBER	13	1.9%	4.2%	1.9%	5.0%	1.8%	6.6%
TRANSPORTATION EQUIP	4	.9%	.7%	1.0%	2.5%	1.1%	1.8%
TRUCKING	4						
TOTALS	814	1.8%	10.2%	1.7%	11.2%	1.9%	11.7%

TABLE 9

R & D PROFILE OF THE 37 SECTORS OF COMPANIES FOR 1976
COMPANIES REPORTING ENERGY R & D IN 1976
(Dollars in Millions)

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
AEROSPACE	17	5	404.8	14.8	2.8%	3.7%
AIRLINE	7	0				
APPLIANCES	12	1				
AUTO: CARS, TRUCKS	8	2	292.8	19.1	1.7%	6.5%
AUTO: PARTS, EQUIP	25	4	43.5	11.6	1.6%	26.7%
BUILDING MATERIALS	30	7	120.8	12.5	1.6%	10.3%
CHEMICALS	62	21	1164.8	104.4	2.8%	9.0%
COMPUTERS	26	0	0	0		
CONGLOMERATES	18	4	37	4.2	.7%	11.4%
CONSTRUCTION	4	2	12.5	10.7	.7%	85.6%
CONTAINERS	7	2	45.8	8.3	1.3%	18.1%
DRUGS	27	2	91.6	6.7	4.5%	7.3%
ELECTRICAL	31	9	632.3	134.2	2.5%	21.2%
ELECTRIC POWER	16	13	115.9	105.9	.7%	91.4%
ELECTRONICS	45	11	33.8	13.2	2.2%	41.5%
FOOD, BEVERAGES	57	6	57.3	1.5	.6%	2.6%
FUELS	42	15	478.2	225.4	.5%	47.1%
GENERAL MACHINERY	74	11	96	34.2	1.6%	35.7%
INSTRUMENTS	40	7	43.8	3	3.1%	6.8%
LEISURE TIME	17	3	42.9	6.7	2.9%	15.6%
METALS + MINING	31	5	120.3	12.5	.7%	10.4%
MISCELLANEOUS MFG.	61	5	67.7	22.9	1.9%	33.7%
NATURAL GAS	8	3	13.9	13.9	.3%	100.0%
OFFICE EQUIPMENT	11	2	223.5	0.2	5.0%	.1%
OIL SERVICE + SUPPLY	16	3	33.1	31.9	.6%	96.5%
PAPER	21	7	42.9	3.7	.6%	8.5%
PERSONAL + HOME CARE	18	2	154.5	0.4	2.6%	.2%
PUBLISHING, PRINTING	6	0				
RADIO, TV, MOVIES	2	0				
RAILROAD	5	0				
SEMICONDUCTORS	10	0				
SERVICES	17	4	10.1	2.3	.1%	22.9%
TELECOMMUNICATIONS	6	1				
TEXTILES, APPAREL	16	6	16.4	1.9	.6%	11.7%
TIRES + RUBBER	13	3	81.7	3.4	1.9%	4.2%
TRANSPORTATION EQUIP	4	1				
TRUCKING	4	0				
TOTALS	914	167	5304.4	823	1.6%	15.5%

TABLE 10

R & D PROFILE OF THE 37 SECTORS OF COMPANIES IN 1977
COMPANIES REPORTING ENERGY R & D IN 1977
(Dollars in Millions)

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
AEROSPACE	17	5	466.3	15.9	3.0%	3.4%
AIRLINE	7	0				
APPLIANCES	12	1				
AUTO: CARS,TRUCKS	9	2	350	29.3	1.9%	8.4%
AUTO:PARTS,EQUIP	25	5	51.4	14.2	1.5%	27.6%
BUILDING MATERIALS	30	7	146.2	15.4	1.7%	10.6%
CHEMICALS	62	26	1428.5	100.2	2.8%	7.0%
COMPUTERS	26	0				
CONGLOMERATES	18	5	649.8	23.1	3.4%	3.6%
CONSTRUCTION	4	1				
CONTAINERS	7	2	46.4	10.2	1.2%	22.0%
DRUGS	27	1				
ELECTRICAL	31	9	704.1	174.4	2.4%	24.8%
ELECTRIC POWER	16	14	147.6	142.4	.7%	96.5%
ELECTRONICS	45	11	47.5	15.6	1.9%	32.8%
FOOD, BEVERAGES	57	7	65.4	1.6	.6%	2.5%
FUELS	42	15	520.8	240.7	.5%	46.2%
GENERAL MACHINERY	74	12	83.5	36.9	1.2%	44.2%
INSTRUMENTS	40	7	50.5	3.2	3.1%	6.4%
LEISURE TIME	17	3	46.1	8	2.8%	17.3%
METALS + MINING	31	5	112.2	19.5	.6%	17.4%
MISCELLANEOUS MFG.	61	6	65.7	26.9	2.0%	41.0%
NATURAL GAS	8	3	10.1	10.1	.2%	100.0%
OFFICE EQUIPMENT	11	2	271.6	0.4	5.2%	.2%
OIL SERVICE + SUPPLY	16	3	38.4	36.7	.6%	95.5%
PAPER	21	6	23.8	3.3	.7%	13.9%
PERSONAL + HOME CARE	19	1				
PUBLISHING,PRINTING	6	0				
RADIO,TV,MOVIES	2	0				
RAILROAD	5	0				
SEMICONDUCTORS	10	0				
SERVICES	17	4	11.9	3.3	.1%	28.0%
TELECOMMUNICATIONS	6	1				
TEXTILES, APPAREL	16	7	16.4	2.1	.4%	12.9%
TIRES + RUBBER	13	3	92.4	4.6	1.9%	5.0%
TRANSPORTATION EQUIP	4	1				
TRUCKING	4	0				
TOTALS	914	175	6290.3	944.8	1.7%	15.0%

TABLE 11

R & D PROFILE OF THE 37 SECTORS OF COMPANIES IN 1978
COMPANIES REPORTING ENERGY R & D IN 1978
(Dollars in Millions)

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
AEROSPACE	17	5	580.7	20.9	3.3%	3.6%
AIRLINE	7	1				
APPLIANCES	12	1				
AUTO: CARS, TRUCKS	8	2	356.8	41.3	2.4%	11.6%
AUTO:PARTS,EQUIP	25	4	56.2	16.2	1.6%	28.8%
BUILDING MATERIALS	30	8	168.7	17.3	1.5%	10.3%
CHEMICALS	62	24	1509.5	121.3	2.8%	8.0%
COMPUTERS	26	0				
CONGLOMERATES	19	6	848.4	28.9	3.9%	3.4%
CONSTRUCTION	4	1				
CONTAINERS	7	2	47.2	10.9	1.1%	23.1%
DRUGS	27	1				
ELECTRICAL	31	10	878.6	203.9	2.6%	23.2%
ELECTRIC POWER	16	14	157.2	153	.7%	97.4%
ELECTRONICS	45	12	58.4	21	2.0%	35.9%
FOOD, BEVERAGES	57	7	56.7	1.7	.6%	3.0%
FUELS	42	15	582	290.9	.5%	50.0%
GENERAL MACHINERY	74	12	89.9	42.4	1.1%	47.2%
INSTRUMENTS	40	7	56.7	4.2	3.1%	7.4%
LEISURE TIME	17	3	46.7	8.9	2.5%	19.2%
METALS + MINING	31	4	113.6	13.4	.5%	11.8%
MISCELLANEOUS MFG.	61	7	73.2	33.5	1.6%	45.8%
NATURAL GAS	8	3	9.4	9.4	.2%	100.0%
OFFICE EQUIPMENT	11	2	314.1	0.7	5.1%	.2%
OIL SERVICE + SUPPLY	16	3	48.3	47.4	.6%	98.1%
PAPER	21	7	59.7	3.9	.7%	6.5%
PERSONAL + HOME CARE	18	1				
PUBLISHING,PRINTING	6	0				
RADIO,TV,MOVIES	2	0				
RAILROAD	5	0				
SEMICONDUCTORS	10	0				
SERVICES	17	4	14.6	3.7	.1%	25.2%
TELECOMMUNICATIONS	6	1				
TEXTILES, APPAREL	16	6	17.4	2.1	.5%	11.9%
TIRES + RUBBER	13	3	100.7	6.7	1.8%	6.6%
TRANSPORTATION EQUIP	4	1				
TRUCKING	4	0				
TOTALS	914	177	7195.8	1114.7	1.7%	15.5%

TABLE 12

YEAR TO YEAR COMPARISON OF R&D PERCENTAGES FOR THE 37 SECTORS
COMPANIES REPORTING ENERGY R&D

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	1976 R+D/ SALES	1976 ENERGY/ TOTAL R+D	1977 R+D/ SALES	1977 ENERGY/ TOTAL R+D	1978 R+D/ SALES	1978 ENERGY/ TOTAL R+D
AEROSPACE	17	2.8%	3.7%	3.0%	3.4%	3.3%	3.6%
AIRLINE	7					.1%	100.0%
APPLIANCES	12						
AUTO: CARS,TRUCKS	8	1.7%	6.5%	1.9%	8.4%	2.4%	11.6%
AUTO:PARTS,EQUIP	25	1.6%	26.7%	1.5%	27.6%	1.6%	28.8%
BUILDING MATERIALS	30	1.6%	10.3%	1.7%	10.6%	1.5%	10.3%
CHEMICALS	62	2.8%	9.0%	2.8%	7.0%	2.8%	8.0%
COMPUTERS	26						
CONGLOMERATES	18	.7%	11.4%	3.4%	3.6%	3.9%	3.4%
CONSTRUCTION	4	.7%	85.6%				
CONTAINERS	7	1.3%	18.1%	1.2%	22.0%	1.1%	23.1%
DRUGS	27	4.5%	7.3%				
ELECTRICAL	31	2.5%	21.2%	2.4%	24.8%	2.6%	23.2%
ELECTRIC POWER	16	.7%	91.4%	.7%	96.5%	.7%	97.4%
ELECTRONICS	45	2.2%	41.5%	1.9%	32.8%	2.0%	35.9%
FOOD, BEVERAGES	57	.6%	2.6%	.6%	2.5%	.6%	3.0%
FUELS	42	.5%	47.1%	.5%	46.2%	.5%	50.0%
GENERAL MACHINERY	74	1.6%	35.7%	1.2%	44.2%	1.1%	47.2%
INSTRUMENTS	40	3.1%	6.8%	3.1%	6.4%	3.1%	7.4%
LEISURE TIME	17	2.9%	15.6%	2.8%	17.3%	2.5%	19.2%
METALS + MINING	31	.7%	10.4%	.6%	17.4%	.5%	11.8%
MISCELLANEOUS MFG.	61	1.9%	33.7%	2.0%	41.0%	1.6%	45.8%
NATURAL GAS	8	.3%	100.0%	.2%	100.0%	.2%	100.0%
OFFICE EQUIPMENT	11	5.0%	.1%	5.2%	.2%	5.1%	.2%
OIL SERVICE + SUPPLY	16	.6%	96.5%	.6%	95.5%	.6%	98.1%
PAPER	21	.6%	8.5%	.7%	13.9%	.7%	6.5%
PERSONAL + HOME CARE	18	2.6%	.2%				
PUBLISHING,PRINTING	6						
RADIO,TV,MOVIES	2						
RAILROAD	5						
SEMICONDUCTORS	10						
SERVICES	17	.1%	22.9%	.1%	28.0%	.1%	25.2%
TELECOMMUNICATIONS	6						
TEXTILES, APPAREL	16	.6%	11.7%	.4%	12.9%	.5%	11.9%
TIRES + RUBBER	13	1.9%	4.2%	1.9%	5.0%	1.8%	6.6%
TRANSPORTATION EQUIP	4						
TRUCKING	4						
TOTALS	814	1.6%	15.5%	1.7%	15.0%	1.7%	15.5%

TABLE 13

MAPPING OF COMPANY SECTORS TO MAJOR GROUPS

Sector	No. of Responses	Sector No.	Corresponding Major Group
AEROSPACE	11	1	HIGH TECHNOLOGY COMPANIES
AIRLINE	4	2	MISCELLANEOUS COMPANIES
APPLIANCES	2	3	ELECTRICAL EQUIPMENT
AUTO: CARS,TRUCKS	3	4	MISCELLANEOUS COMPANIES
AUTO:PARTS,EQUIP	10	5	LIGHT INDUSTRY
BUILDING MATERIALS	12	6	BUILDING MATERIALS,METALS+MINING
CHEMICALS	44	7	CHEMICALS
COMPUTERS	8	8	HIGH TECHNOLOGY COMPANIES
CONGLOMERATES	11	9	MISCELLANEOUS COMPANIES
CONSTRUCTION	3	10	MISCELLANEOUS COMPANIES
CONTAINERS	5	11	CONSUMER GOODS
DRUGS	15	12	CONSUMER GOODS
ELECTRICAL	16	13	ELECTRICAL EQUIPMENT
ELECTRIC POWER	14	14	ELECTRIC POWER
ELECTRONICS	29	15	HIGH TECHNOLOGY COMPANIES
FOOD, BEVERAGES	25	16	CONSUMER GOODS
FUELS	25	17	COAL, OIL AND GAS
GENERAL MACHINERY	35	18	GENERAL MACHINERY
INSTRUMENTS	17	19	HIGH TECHNOLOGY COMPANIES
LEISURE TIME	4	20	LIGHT INDUSTRY
METALS + MINING	16	21	BUILDING MATERIALS,METALS+MINING
MISCELLANEOUS MFG.	31	22	LIGHT INDUSTRY
NATURAL GAS	3	23	COAL, OIL AND GAS
OFFICE EQUIPMENT	7	24	LIGHT INDUSTRY
OIL SERVICE + SUPPLY	9	25	COAL, OIL AND GAS
PAPER	12	26	MISCELLANEOUS COMPANIES
PERSONAL + HOME CARE	8	27	CONSUMER GOODS
PUBLISHING,PRINTING	1	28	MISCELLANEOUS COMPANIES
RADIO,TV,MOVIES	1	29	MISCELLANEOUS COMPANIES
RAILROAD		30	MISCELLANEOUS COMPANIES
SEMICONDUCTORS	2	31	HIGH TECHNOLOGY COMPANIES
SERVICES	6	32	MISCELLANEOUS COMPANIES
TELECOMMUNICATIONS	5	33	HIGH TECHNOLOGY COMPANIES
TEXTILES, APPAREL	9	34	CONSUMER GOODS
TIRES + RUBBER	3	35	LIGHT INDUSTRY
TRANSPORTATION EQUIP	3	36	GENERAL MACHINERY
TRUCKING	3	37	MISCELLANEOUS COMPANIES

TABLE 14

R&D PROFILES OF THE 10 MAJOR GROUPS OF ALL COMPANIES FOR 1976 - 1977 - 1978
INCLUDING THOSE REPORTING ZERO ENERGY R&D
(Dollars in Millions)

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
HIGH TECHNOLOGY COMPANIES	144	61	2272.9	39.1	6.2%	1.7%
CHEMICALS	62	36	1363.3	104.4	2.8%	7.7%
COAL, OIL AND GAS	66	29	525.3	271.2	.5%	51.6%
CONSUMER GOODS	125	58	1009.2	18.8	1.7%	1.9%
GENERAL MACHINERY	78	32	212.4	34.4	1.5%	16.2%
ELECTRICAL EQUIPMENT	43	16	729.6	138.5	2.5%	19.0%
LIGHT INDUSTRY	127	45	538.9	44.7	2.4%	8.3%
MISCELLANEOUS COMPANIES	92	38	1033	40	1.5%	3.9%
ELECTRIC POWER	16	14	116.9	106.9	.6%	91.4%
BUILDING MATERIALS, METALS+MINING	61	22	254	25	.8%	9.8%
TOTALS	814	351	8055.6	823	1.8%	10.2%

SECTOR			TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
HIGH TECHNOLOGY COMPANIES	s	s	2022.6	38.6	4.8%	1.9%
CHEMICALS	e	e	1495	100.2	2.8%	6.7%
COAL, OIL AND GAS	e	e	569.2	287.5	.5%	50.5%
CONSUMER GOODS			1118.4	14.1	1.5%	1.3%
GENERAL MACHINERY	a	a	213	37.8	1.3%	17.8%
ELECTRICAL EQUIPMENT	b	b	770	175.1	2.3%	22.7%
LIGHT INDUSTRY	o	o	608.8	54.2	2.3%	8.9%
MISCELLANEOUS COMPANIES	v	v	1190.2	59.9	1.8%	5.0%
ELECTRIC POWER	e	e	147.6	142.4	.7%	96.5%
BUILDING MATERIALS, METALS+MINING			277.6	35	.7%	12.6%
TOTALS			8412.5	944.8	1.7%	11.2%

SECTOR			TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
HIGH TECHNOLOGY COMPANIES	s	s	2413.5	50.1	6.2%	2.1%
CHEMICALS	e	e	1603.2	121.3	2.7%	7.6%
COAL, OIL AND GAS	e	e	639.7	347.7	.5%	54.3%
CONSUMER GOODS			1250.7	15	1.9%	1.2%
GENERAL MACHINERY	a	a	236.3	43.2	1.3%	18.3%
ELECTRICAL EQUIPMENT	b	b	922.6	204.6	2.5%	22.2%
LIGHT INDUSTRY	o	o	647.9	66	2.5%	10.2%
MISCELLANEOUS COMPANIES	v	v	1345.9	83	1.8%	6.2%
ELECTRIC POWER	e	e	157.2	153	.7%	97.4%
BUILDING MATERIALS, METALS+MINING			322.5	30.8	.9%	9.5%
TOTALS			9539.6	1114.7	1.9%	11.7%

TABLE 15

YEAR TO YEAR COMPARISON OF R&D PERCENTAGES FOR THE 10 MAJOR GROUPS OF ALL COMPANIES INCLUDING THOSE REPORTING ZERO ENERGY R&D

SECTOR	1976 R+D/ SALES	1976 ENERGY/ TOTAL R+D	1977 R+D/ SALES	1977 ENERGY/ TOTAL R+D	1978 R+D/ SALES	1978 ENERGY/ TOTAL R+D
HIGH TECHNOLOGY COMPANIES	6.2%	1.7%	4.8%	1.9%	6.2%	2.1%
CHEMICALS	2.8%	7.7%	2.8%	6.7%	2.7%	7.6%
COAL, OIL AND GAS	.5%	51.6%	.5%	50.5%	.5%	54.3%
CONSUMER GOODS	1.7%	1.9%	1.5%	1.3%	1.9%	1.2%
GENERAL MACHINERY	1.5%	16.2%	1.3%	17.8%	1.3%	18.3%
ELECTRICAL EQUIPMENT	2.5%	19.0%	2.3%	22.7%	2.5%	22.2%
LIGHT INDUSTRY	2.4%	8.3%	2.3%	8.9%	2.5%	10.2%
MISCELLANEOUS COMPANIES	1.5%	3.9%	1.8%	5.0%	1.8%	6.2%
ELECTRIC POWER	.6%	91.4%	.7%	96.5%	.7%	97.4%
BUILDING MATERIALS, METALS+MINING	.8%	9.8%	.7%	12.6%	.9%	9.5%
TOTALS	1.8%	10.2%	1.7%	11.2%	1.9%	11.7%

TABLE 16

R&D PROFILE OF THE 10 MAJOR GROUPS OF COMPANIES 1976 - 1978
COMPANIES REPORTING ENERGY R&D
(Dollars in Millions)

1976

SECTOR	NUMBER RECEIVING QUESTIONNAIRE	NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
HIGH TECHNOLOGY COMPANIES	144	24	1252.4	39.1	6.7%	3.1%
CHEMICALS	62	21	1164.8	104.4	2.8%	9.0%
COAL, OIL AND GAS	66	21	525.1	271.2	.5%	51.6%
CONSUMER GOODS	125	18	365.6	18.8	1.5%	5.2%
GENERAL MACHINERY	78	12	121	34.4	1.4%	28.5%
ELECTRICAL EQUIPMENT	43	10	657.7	138.5	2.4%	21.1%
LIGHT INDUSTRY	127	17	464.3	44.7	2.8%	9.6%
MISCELLANEOUS COMPANIES	92	19	395.4	40	1.0%	10.1%
ELECTRIC POWER	16	13	116.9	106.9	.7%	91.4%
BUILDING MATERIALS,METALS+MINING	61	12	241.1	25	.9%	10.4%
TOTALS	814	167	5304.4	823	1.6%	15.5%

1977

SECTOR		NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
HIGH TECHNOLOGY COMPANIES	see above	24	1314.3	38.6	6.4%	2.9%
CHEMICALS		26	1428.5	100.2	2.8%	7.0%
COAL, OIL AND GAS		21	569.2	287.5	.5%	50.5%
CONSUMER GOODS		18	144.3	14.1	.7%	9.8%
GENERAL MACHINERY		13	116.5	37.8	1.2%	32.5%
ELECTRICAL EQUIPMENT		10	733.3	175.1	2.3%	23.9%
LIGHT INDUSTRY		19	527.2	54.2	2.8%	10.3%
MISCELLANEOUS COMPANIES		18	1041	59.9	2.0%	5.8%
ELECTRIC POWER		14	147.6	142.4	.7%	96.5%
BUILDING MATERIALS,METALS+MINING		12	258.4	35	.9%	13.5%
TOTALS		175	6280.3	944.8	1.7%	15.0%

1978

SECTOR		NUMBER RESPONSES	TOTAL R+D	TOTAL ENERGY R+D	R+D/ SALES	ENERGY/ TOTAL R+D
HIGH TECHNOLOGY COMPANIES	see above	25	1565.8	50.1	6.8%	3.2%
CHEMICALS		24	1509.5	121.3	2.8%	8.0%
COAL, OIL AND GAS		21	639.7	347.7	.5%	54.3%
CONSUMER GOODS		17	139.9	15	.8%	10.7%
GENERAL MACHINERY		13	129.9	43.2	1.2%	33.3%
ELECTRICAL EQUIPMENT		11	891.3	204.6	2.5%	23.0%
LIGHT INDUSTRY		19	590.9	66	2.8%	11.2%
MISCELLANEOUS COMPANIES		21	1289.2	83	2.0%	6.4%
ELECTRIC POWER		14	157.2	153	.7%	97.4%
BUILDING MATERIALS,METALS+MINING		12	282.3	30.8	.9%	10.9%
TOTALS		177	7195.8	1114.7	1.7%	15.5%

APPENDIX D

Relative Importance of Each Technology Area

for DOE Support

and

Opinions of Government Sponsorship Levels

TABLE 17

RELATIVE IMPORTANCE INDEX FOR ALL RESPONDENTS
AND ALL REPORTING SPENDING IN CATEGORY
AND IN TECHNOLOGY.
(TECHNOLOGIES WITH FEWER THAN 4 RESPONSES OMITTED)

CATEGORY / TECHNOLOGY	All	All reporting spending somewhere in category	All reporting spending in technology
MANUFACTURING/PROCESS CHANGES			
RAW MATERIAL CHANGES	413	429	386
CHEMICAL / REFINING PROCESSES	433	406	381
NEW ENERGY SAVING PROCESSES	613	585	586
IMPROVED ENERGY SAVING PROCESSES	550	521	549
OTHER MANUFACTURING/PROCESS CHANGES	375		
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY			
RESIDENTIAL HEAT PUMPS	458	530	707
INDUSTRIAL HEAT PUMPS	456	526	640
PROCESS HEAT RECOVERY	560	639	672
USE OF LOW PRESSURE EXHAUST STEAM	476	547	700
OTHER HEAT RECOVERY SYSTEMS	375		
END PRODUCT EFFICIENCY			
CONSUMER APPLIANCES	444	460	523
MANUFACTURING EQUIPMENT	443	506	508
BUILDING INSULATION	528	585	588
ENERGY EFFICIENT BUILDINGS	606	645	729
TRANSPORTATION			
AUTOMOTIVE ENGINE	562	541	563
AUTOMOTIVE CHASSIS AND BODY	379	348	575
ELECTRIC / HYBRID VEHICLES	537	624	850
OTHER AUTOMOTIVE	256	250	
RAIL TRANSPORTATION/EQUIPMENT	495	500	550
AIRCRAFT ENGINE AND AIRFRAME	483	552	650
PIPELINE TECHNOLOGIES	435	400	453
MARINE TRANSPORTATION / EQUIPMENT	407	409	600

TABLE 17 (Continued)

Category/Technology	All	All reporting spending somewhere in category	All reporting spending in technology
ELECTRIC POWER GENERATION			
GAS TURBINE COMBINED CYCLE	553	824	783
FUEL CELLS	641	809	850
MAGNETOHYDRODYNAMIC GENERATION	588	659	580
CRYOGENIC GENERATORS	452	593	
TRANSMISSION AND DISTRIBUTION	498	625	688
LOW HEAD HYDROELECTRIC	499	471	
FLUIDIZED BEDS	548	755	829
INDUSTRIAL COMBUSTION AND STEAM GENERATION			
COGENERATION	555	596	521
ATMOSPHERIC FLUIDIZED BED	543	561	643
COAL / OIL SLURRY	523	433	427
WASTE MATERIAL	650	674	695
INSTRUMENTATION AND CONTROL	435	479	620
ENERGY STORAGE			
PUMPED HYDRO STORAGE	387	492	
COMPRESSED AIR STORAGE	366	569	560
THERMAL ENERGY STORAGE	550	663	730
BATTERIES	655	791	817
HYDROGEN GENERATION	577	583	
OIL			
SECONDARY OIL RECOVERY	572	395	317
TERTIARY OIL RECOVERY	642	642	683
MATERIALS FOR ENHANCED OIL RECOVERY	620	585	592
HEAVY OIL	530	489	500
TAR SANDS	581	515	557
OIL SHALE	630	612	655
GEOLOGICAL ASSESSMENT TECHNIQUES	601	467	350
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	549	347	175

TABLE 17 (Continued)

Category/Technology	All	All reporting spending somewhere in category	All reporting spending in technology
GAS			
ENHANCED GAS RECOVERY	634	480	425
GEOPRESSURE METHANE	652	583	
TIGHT SANDS	570	575	425
DEVONIAN SHALE	570	560	
COAL			
PREPARATION	471	553	576
MINING	503	581	525
GASIFICATION	742	824	850
LIQUEFACTION	730	867	914
CHEMICAL FEEDSTOCKS	554	576	667
NUCLEAR			
FUEL PRODUCTION	717	731	800
FUEL SEPARATION	751	800	
REPROCESSING	816	859	
WASTE DISPOSAL	862	875	733
LIQUID METAL FAST BREEDER	810	943	977
OTHER BREEDER	704	773	
REACTOR FOR INDUSTRIAL PROCESS USE	538	514	
LIGHT WATER REACTORS	662	714	820
OTHER FISSION	628	700	
FUSION	844	829	850
SOLAR AND OTHER RENEWABLE			
SOLAR PHOTOVOLTAIC	697	690	794
SOLAR THERMAL POWER GENERATION	649	618	720
SOLAR INDUSTRIAL PROCESS HEAT	604	576	667
HEATING AND COOLING	659	681	661
BIOMASS	640	605	695
MUNICIPAL SOLID WASTE	662	643	825
TIDAL	443	353	
OCEAN THERMAL	490	392	550
GEOTHERMAL	547	550	583
WIND	537	482	583

TABLE 18

RELATIVE IMPORTANCE INDEX FOR ALL COMPANIES REPORTING
(TECHNOLOGIES WITH FEWER THAN 4 RESPONSES OMITTED.)

CATEGORY / TECHNOLOGY	TOTAL	PERCENTAGE NS	NI	I	VI	IMPORTANCE INDEX
MANUFACTURING/PROCESS CHANGES						
RAW MATERIAL CHANGES	109	37	18	37	8	413
CHEMICAL / REFINING PROCESSES	103	37	14	39	11	433
NEW ENERGY SAVING PROCESSES	139	22	8	39	31	613
IMPROVED ENERGY SAVING PROCESSES	132	27	10	39	23	550
OTHER MANUFACTURING/PROCESS CHANGES	4	25	50	25		375
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY						
RESIDENTIAL HEAT PUMPS	109	33	19	32	16	458
INDUSTRIAL HEAT PUMPS	107	34	17	36	14	456
PROCESS HEAT RECOVERY	117	27	10	35	27	560
USE OF LOW PRESSURE EXHAUST STEAM	101	28	23	37	13	476
OTHER HEAT RECOVERY SYSTEMS	4	25	50	25		375
END PRODUCT EFFICIENCY						
CONSUMER APPLIANCES	106	35	18	33	14	444
MANUFACTURING EQUIPMENT	105	34	22	28	16	443
BUILDING INSULATION	111	29	12	38	22	528
ENERGY EFFICIENT BUILDINGS	116	22	9	41	28	606
TRANSPORTATION						
AUTOMOTIVE ENGINE	109	28	15	25	33	562
AUTOMOTIVE CHASSIS AND BODY	94	40	20	32	7	379
ELECTRIC / HYBRID VEHICLES	102	22	21	41	17	537
OTHER AUTOMOTIVE	34	56	21	21	3	256
RAIL TRANSPORTATION/EQUIPMENT	96	27	21	36	16	495
AIRCRAFT ENGINE AND AIRFRAME	93	27	22	40	12	483
PIPELINE TECHNOLOGIES	96	30	29	29	11	435
MARINE TRANSPORTATION / EQUIPMENT	89	30	33	31	6	407

TABLE 18 (Continued)

Category/Technology	Total	Percentage NS	NI	I	VI	Importance Index
ELECTRIC POWER GENERATION						
GAS TURBINE COMBINED CYCLE	90	23	18	36	23	553
FUEL CELLS	97	9	19	52	21	641
MAGNETOHYDRODYNAMIC GENERATION	89	11	25	51	13	588
CRYOGENIC GENERATORS	75	24	33	36	7	452
TRANSMISSION AND DISTRIBUTION	93	28	20	33	18	498
LOW HEAD HYDROELECTRIC	88	20	26	47	7	499
FLUIDIZED BEDS	94	21	20	39	19	548
INDUSTRIAL COMBUSTION AND STEAM GENERATION						
COGENERATION	95	22	16	43	19	555
ATMOSPHERIC FLUIDIZED BED	89	22	18	42	18	543
COAL / OIL SLURRY	96	24	22	35	19	523
WASTE MATERIAL	108	11	12	56	21	650
INSTRUMENTATION AND CONTROL	95	35	24	24	17	435
ENERGY STORAGE						
PUMPED HYDRO STORAGE	83	35	29	30	6	387
COMPRESSED AIR STORAGE	79	34	37	24	5	366
THERMAL ENERGY STORAGE	94	19	19	48	14	550
BATTERIES	99	15	14	36	34	655
HYDROGEN GENERATION	98	19	17	42	21	577
OIL						
SECONDARY OIL RECOVERY	98	27	11	32	31	572
TERTIARY OIL RECOVERY	97	21	8	34	37	642
MATERIALS FOR ENHANCED OIL RECOVERY	97	22	10	34	34	620
HEAVY OIL	76	24	16	46	14	530
TAR SANDS	90	16	21	46	18	581
OIL SHALE	98	15	13	46	26	630
GEOLOGICAL ASSESSMENT TECHNIQUES	88	20	16	33	31	601
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	87	26	16	30	28	549

TABLE 18 (Continued)

Category/Technology	Total	Percentage NS	NI	I	VI	Importance Index
GAS						
ENHANCED GAS RECOVERY	99	23	7	30	39	634
GEOPRESSURE METHANE	96	17	11	38	34	652
TIGHT SANDS	82	21	16	43	21	570
DEVONIAN SHALE	77	21	16	43	21	570
COAL						
PREPARATION	98	33	18	31	18	471
MINING	101	31	18	28	24	503
GASIFICATION	116	9	8	39	44	742
LIQUEFACTION	108	12	8	33	46	730
CHEMICAL FEEDSTOCKS	90	26	13	37	24	554
NUCLEAR						
FUEL PRODUCTION	93	9	14	38	40	717
FUEL SEPARATION	92	8	10	38	45	751
REPROCESSING	96	6	7	26	60	816
WASTE DISPOSAL	112	4	7	17	71	862
LIQUID METAL FAST BREEDER	101	6	6	32	56	810
OTHER BREEDER	51	14	14	25	47	704
REACTOR FOR INDUSTRIAL PROCESS USE	82	20	32	26	23	538
LIGHT WATER REACTORS	81	12	17	37	33	662
OTHER FISSION	47	15	23	28	34	628
FUSION	103	5	5	26	64	844
SOLAR AND OTHER RENEWABLE						
SOLAR PHOTOVOLTAIC	107	6	21	41	33	697
SOLAR THERMAL POWER GENERATION	104	8	25	41	26	649
SOLAR INDUSTRIAL PROCESS HEAT	100	12	25	42	21	604
HEATING AND COOLING	99	11	16	44	28	659
BIOMASS	103	8	19	55	17	640
MUNICIPAL SOLID WASTE	103	12	16	43	30	662
TIDAL	95	23	40	28	8	443
OCEAN THERMAL	97	19	37	34	10	490
GEOTHERMAL	98	9	39	43	9	547
WIND	101	15	31	44	11	537

TABLE 19

RELATIVE IMPORTANCE INDEX FOR ALL COMPANIES REPORTING SPENDING IN THE CATEGORY
(TECHNOLOGIES WITH FEWER THAN 4 RESPONSES OMITTED.)

CATEGORY / TECHNOLOGY	TOTAL	PERCENTAGE NS	NI	I	VI	IMPORTANCE INDEX
MANUFACTURING/PROCESS CHANGES						
RAW MATERIAL CHANGES	72	38	14	38	11	429
CHEMICAL / REFINING PROCESSES	64	41	13	38	9	406
NEW ENERGY SAVING PROCESSES	93	25	9	39	28	585
IMPROVED ENERGY SAVING PROCESSES	87	31	11	33	24	521
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY						
RESIDENTIAL HEAT PUMPS	37	24	22	32	22	530
INDUSTRIAL HEAT PUMPS	35	29	14	34	23	526
PROCESS HEAT RECOVERY	46	22	7	35	37	639
USE OF LOW PRESSURE EXHAUST STEAM	34	21	26	29	24	547
END PRODUCT EFFICIENCY						
CONSUMER APPLIANCES	30	40	10	27	23	460
MANUFACTURING EQUIPMENT	31	29	19	29	23	506
BUILDING INSULATION	34	26	6	38	29	585
ENERGY EFFICIENT BUILDINGS	42	19	7	40	33	645
TRANSPORTATION						
AUTOMOTIVE ENGINE	34	26	18	29	26	541
AUTOMOTIVE CHASSIS AND BODY	25	40	24	36		348
ELECTRIC / HYBRID VEHICLES	29	14	17	45	24	624
OTHER AUTOMOTIVE	6	50	33	17		250
RAIL TRANSPORTATION/EQUIPMENT	27	22	26	41	11	500
AIRCRAFT ENGINE AND AIRFRAME	27	15	22	56	7	552
PIPELINE TECHNOLOGIES	28	32	32	29	7	400
MARINE TRANSPORTATION / EQUIPMENT	22	32	32	27	9	409

TABLE 19 (Continued)

Category/Technology	Total	Percentage NS	NI	I	VI	Importance Index
ELECTRIC POWER GENERATION						
GAS TURBINE COMBINED CYCLE	21	5	5	33	57	824
FUEL CELLS	22		5	55	41	809
MAGNETOHYDRODYNAMIC GENERATION	22		32	50	18	659
CRYOGENIC GENERATORS	15	7	33	47	13	593
TRANSMISSION AND DISTRIBUTION	24	13	21	42	25	625
LOW HEAD HYDROELECTRIC	17	18	35	47		471
FLUIDIZED BEDS	22		9	64	27	755
INDUSTRIAL COMBUSTION AND STEAM GENERATION						
COGENERATION	25	20	8	52	20	596
ATMOSPHERIC FLUIDIZED BED	23	22	13	48	17	561
COAL / OIL SLURRY	24	29	25	42	4	433
WASTE MATERIAL	31	6	13	61	19	674
INSTRUMENTATION AND CONTROL	29	34	17	24	24	479
ENERGY STORAGE						
PUMPED HYDRO STORAGE	13	23	23	46	8	492
COMPRESSED AIR STORAGE	13	15	23	46	15	569
THERMAL ENERGY STORAGE	19	5	21	53	21	663
BATTERIES	22	5	5	45	45	791
HYDROGEN GENERATION	18	17	17	50	17	583
OIL						
SECONDARY OIL RECOVERY	22	45	9	32	14	395
TERTIARY OIL RECOVERY	24	21	4	42	33	642
MATERIALS FOR ENHANCED OIL RECOVERY	27	26	4	44	26	585
HEAVY OIL	18	28	11	56	6	489
TAR SANDS	20	20	20	55	5	515
OIL SHALE	25	16	8	60	16	612
GEOLOGICAL ASSESSMENT TECHNIQUES	18	33	17	33	17	467
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	17	53	6	29	12	347

TABLE 19 (Continued)

Category/Technology	Total	NS	NI	I	VI	Importance Index
		Percentage				
GAS						
ENHANCED GAS RECOVERY	15	40	7	27	27	480
GEOPRESSURE METHANE	12	17	8	67	8	583
TIGHT SANDS	12	25	8	42	25	575
DEVONIAN SHALE	10	20	20	40	20	560
COAL						
PREPARATION	34	24	12	47	18	553
MINING	36	19	17	42	22	581
GASIFICATION	41		5	49	46	824
LIQUEFACTION	36		8	28	64	867
CHEMICAL FEEDSTOCKS	25	16	20	48	16	576
NUCLEAR						
FUEL PRODUCTION	16	6	13	44	38	731
FUEL SEPARATION	14	7		43	50	800
REPROCESSING	17			47	53	859
WASTE DISPOSAL	20	5		25	70	875
LIQUID METAL FAST BREEDER	21			19	81	943
OTHER BREEDER	11	9		45	45	773
REACTOR FOR INDUSTRIAL PROCESS USE	14	14	43	29	14	514
LIGHT WATER REACTORS	14	7		71	21	714
OTHER FISSION	9		22	56	22	700
FUSION	21		5	48	48	829
SOLAR AND OTHER RENEWABLE						
SOLAR PHOTOVOLTAIC	41	2	24	46	27	690
SOLAR THERMAL POWER GENERATION	40	8	25	53	15	618
SOLAR INDUSTRIAL PROCESS HEAT	37	11	27	51	11	576
HEATING AND COOLING	43	12	7	53	28	681
BIOMASS	43	12	21	51	16	605
MUNICIPAL SOLID WASTE	40	13	23	33	33	643
TIDAL	36	31	47	19	3	353
OCEAN THERMAL	36	25	44	31		392
GEOTHERMAL	38	8	37	50	5	550
WIND	39	18	36	41	5	482

TABLE 20

RELATIVE IMPORTANCE INDEX FOR ALL COMPANIES REPORTING SPENDING IN THE TECHNOLOGY
(TECHNOLOGIES WITH FEWER THAN 4 RESPONSES OMITTED.)

CATEGORY / TECHNOLOGY	TOTAL	PERCENTAGE NS	NI	I	VI	IMPORTANCE INDEX
MANUFACTURING/PROCESS CHANGES						
RAW MATERIAL CHANGES	37	46	14	24	16	386
CHEMICAL / REFINING PROCESSES	21	48	5	38	10	381
NEW ENERGY SAVING PROCESSES	63	24	10	40	27	586
IMPROVED ENERGY SAVING PROCESSES	68	28	12	34	26	549
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY						
RESIDENTIAL HEAT PUMPS	14	14		50	36	707
INDUSTRIAL HEAT PUMPS	15	20	7	40	33	640
PROCESS HEAT RECOVERY	36	19	3	39	39	672
USE OF LOW PRESSURE EXHAUST STEAM	8		25	50	25	700
END PRODUCT EFFICIENCY						
CONSUMER APPLIANCES	13	38		31	31	523
MANUFACTURING EQUIPMENT	13	31	8	46	15	508
BUILDING INSULATION	16	19	13	50	19	588
ENERGY EFFICIENT BUILDINGS	24	8	8	46	38	729
TRANSPORTATION						
AUTOMOTIVE ENGINE	8	25	13	38	25	563
AUTOMOTIVE CHASSIS AND BODY	8	13	13	75		575
ELECTRIC / HYBRID VEHICLES	8		13	25	63	850
RAIL TRANSPORTATION/EQUIPMENT	4		50	50		550
AIRCRAFT ENGINE AND AIRFRAME	6		33	50	17	650
PIPELINE TECHNOLOGIES	15	27	27	40	7	453
MARINE TRANSPORTATION / EQUIPMENT	4	25		50	25	600
ELECTRIC POWER GENERATION						
GAS TURBINE COMBINED CYCLE	6	17		17	67	783
FUEL CELLS	8			50	50	850
MAGNETOHYDRODYNAMIC GENERATION	5		40	60		580
TRANSMISSION AND DISTRIBUTION	17	12	12	41	35	688
FLUIDIZED BEDS	7			57	43	829

TABLE 20 (Continued)

Category/Technology	Total	Percentage NS	NI	I	VI	Importance Index
INDUSTRIAL COMBUSTION AND STEAM GENERATION						
COGENERATION	14	29	7	50	14	521
ATMOSPHERIC FLUIDIZED BED	7	14		71	14	643
COAL / OIL SLURRY	11	27	27	45		427
WASTE MATERIAL	21	5	14	57	24	695
INSTRUMENTATION AND CONTROL	15	20	13	33	33	620
ENERGY STORAGE						
COMPRESSED AIR STORAGE	5	20	20	40	20	560
THERMAL ENERGY STORAGE	10		20	50	30	730
BATTERIES	12	8		33	58	817
OIL						
SECONDARY OIL RECOVERY	12	58		33	8	317
TERTIARY OIL RECOVERY	12	17		50	33	683
MATERIALS FOR ENHANCED OIL RECOVERY	12	33	8	3	50	592
HEAVY OIL	7	29		71		500
TAR SANDS	7	14	14	71		557
OIL SHALE	11	18		55	27	655
GEOLOGICAL ASSESSMENT TECHNIQUES	8	50	13	25	13	350
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	8	75		25		175
GAS						
ENHANCED GAS RECOVERY	8	50	13		38	425
TIGHT SANDS	4	50		25	25	425
COAL						
PREPARATION	21	24	10	43	24	576
MINING	16	25	19	38	19	525
GASIFICATION	30			50	50	850
LIQUEFACTION	21			29	71	914
CHEMICAL FEEDSTOCKS	9		22	67	11	667

TABLE 20 (Continued)

Category/Technology	Total	NS	NI	I	VI	Importance Index
NUCLEAR						
FUEL PRODUCTION	6			67	33	800
WASTE DISPOSAL	6	17		33	50	733
LIQUID METAL FAST BREEDER	13			8	92	977
LIGHT WATER REACTORS	5			60	40	820
FUSION	6			50	50	850
SOLAR AND OTHER RENEWABLE						
SOLAR PHOTOVOLTAIC	16		13	44	44	794
SOLAR THERMAL POWER GENERATION	10	10	10	40	40	720
SOLAR INDUSTRIAL PROCESS HEAT	9		22	67	11	667
HEATING AND COOLING	23	13	9	52	26	661
BIOMASS	21	5	10	67	19	695
MUNICIPAL SOLID WASTE	12		17	25	58	825
OCEAN THERMAL	4		50	50		550
GEOTHERMAL	6	17		83		583
WIND	6	17	17	50	17	583

TABLE 21A

Relative Importance Index for the High Technology, Chemicals and Coal, Oil Gas Companies

CATEGORY / TECHNOLOGY	HIGH TECH.		CHEMICALS		COAL, OIL AND GAS	
	Resp.	Index	Resp.	Index	Resp.	Index
MANUFACTURING/PROCESS CHANGES						
RAW MATERIAL CHANGES	15	360	14	229	11	364
CHEMICAL / REFINING PROCESSES	17	576	14	221	11	318
NEW ENERGY SAVING PROCESSES	22	614	15	353	15	573
IMPROVED ENERGY SAVING PROCESSES	22	582	15	440	12	433
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY						
RESIDENTIAL HEAT PUMPS	16	513	11	255	11	473
INDUSTRIAL HEAT PUMPS	15	453	11	345	11	445
PROCESS HEAT RECOVERY	18	561	14	464	11	436
USE OF LOW PRESSURE EXHAUST STEAM	15	393	10	280	11	445
END PRODUCT EFFICIENCY						
CONSUMER APPLIANCES	17	453	11	327	13	408
MANUFACTURING EQUIPMENT	14	400	12	383	14	400
BUILDING INSULATION	17	435	12	542	12	383
ENERGY EFFICIENT BUILDINGS	18	650	12	542	13	431
TRANSPORTATION						
AUTOMOTIVE ENGINE	19	626	12	508	13	338
AUTOMOTIVE CHASSIS AND BODY	14	400	13	438	11	145
ELECTRIC / HYBRID VEHICLES	16	600	11	509	13	331
OTHER AUTOMOTIVE	5	200	-	-	4	100
RAIL TRANSPORTATION/EQUIPMENT	16	569	9	467	13	338
AIRCRAFT ENGINE AND AIRFRAME	15	520	10	430	12	400
PIPELINE TECHNOLOGIES	14	436	11	300	12	358
MARINE TRANSPORTATION / EQUIPMENT	15	473	10	290	10	200

TABLE 21A (continued)

	HIGH TECH.		CHEMICALS		COAL, OIL AND GAS	
ELECTRIC POWER GENERATION	Resp.	Index	Resp.	Index	Resp.	Index
GAS TURBINE COMBINED CYCLE	14	543	12	467	9	467
FUEL CELLS	14	514	11	609	14	714
MAGNETOHYDRODYNAMIC GENERATION	13	623	10	570	10	500
CRYOGENIC GENERATORS	9	411	10	400	8	275
TRANSMISSION AND DISTRIBUTION	16	463	10	250	8	288
LOW HEAD HYDROELECTRIC	13	569	10	290	8	363
FLUIDIZED BEDS	14	600	11	264	10	590
INDUSTRIAL COMBUSTION AND STEAM GENERATION						
COGENERATION	16	544	10	320	11	564
ATMOSPHERIC FLUIDIZED BED	13	592	10	370	9	533
COAL / OIL SLURRY	16	475	10	390	10	430
WASTE MATERIAL	19	589	12	525	10	530
INSTRUMENTATION AND CONTROL	19	532	11	327	10	290
ENERGY STORAGE						
PUMPED HYDRO STORAGE	12	275	10	220	9	289
COMPRESSED AIR STORAGE	10	320	10	290	9	222
THERMAL ENERGY STORAGE	14	550	11	473	9	411
BATTERIES	15	620	10	460	13	785
HYDROGEN GENERATION	16	631	11	509	9	533
OIL						
SECONDARY OIL RECOVERY	14	443	12	542	15	420
TERTIARY OIL RECOVERY	14	486	11	500	15	660
MATERIALS FOR ENHANCED OIL RECOVERY	13	500	14	557	14	479
HEAVY OIL	11	418	11	536	11	509
TAR SANDS	13	515	12	500	12	525
OIL SHALE	14	521	12	575	15	660
GEOLOGICAL ASSESSMENT TECHNIQUES	14	493	10	390	12	467
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	15	527	9	533	12	325

TABLE 21A (continued)

	HIGH TECH.		CHEMICALS		COAL, OIL AND GAS	
	Resp.	Index	Resp.	Index	Resp.	Index
GAS						
ENHANCED GAS RECOVERY	15	527	11	582	15	480
GEOPRESSURE METHANE	15	507	10	510	16	644
TIGHT SANDS	12	525	9	533	14	586
DEVONIAN SHALE	11	509	9	422	12	600
COAL						
PREPARATION	14	400	10	350	13	346
MINING	15	440	11	409	14	386
GASIFICATION	18	739	13	700	17	782
LIQUEFACTION	16	725	13	700	15	747
CHEMICAL FEEDSTOCKS	15	573	12	600	11	391
NUCLEAR						
FUEL PRODUCTION	14	829	10	590	10	500
FUEL SEPARATION	13	908	9	656	12	608
REPROCESSING	15	960	9	756	13	715
WASTE DISPOSAL	19	937	11	882	14	757
LIQUID METAL FAST BREEDER	17	876	9	722	13	738
OTHER BREEDER	8	925	-	-	13	662
REACTOR FOR INDUSTRIAL PROCESS USE	14	571	7	414	12	592
LIGHT WATER REACTORS	14	686	6	533	12	617
OTHER FISSION	7	771	6	517	8	538
FUSION	18	900	9	856	15	833
SOLAR AND OTHER RENEWABLE						
SOLAR PHOTOVOLTAIC	18	817	12	692	12	683
SOLAR THERMAL POWER GENERATION	18	794	11	600	12	525
SOLAR INDUSTRIAL PROCESS HEAT	15	667	11	545	12	608
HEATING AND COOLING	14	621	11	536	11	745
BIOMASS	17	624	13	592	12	658
MUNICIPAL SOLID WASTE	16	631	10	680	13	515
TIDAL	14	500	11	509	12	308
OCEAN THERMAL	16	644	11	600	11	245
GEOTHERMAL	15	640	11	573	13	400
WIND	16	575	11	536	12	533

TABLE 21B

Relative Importance Index for the Consumer Goods, General Machinery and Light Industry Companies

CATEGORY / TECHNOLOGY	CONSUMER GOODS		GENERAL MACHINERY		LIGHT INDUSTRY	
	Resp.	Index	Resp.	Index	Resp.	Index
MANUFACTURING/PROCESS CHANGES						
RAW MATERIAL CHANGES	15	353	13	469	14	607
CHEMICAL / REFINING PROCESSES	16	306	12	475	12	517
NEW ENERGY SAVING PROCESSES	21	538	12	742	16	744
IMPROVED ENERGY SAVING PROCESSES	18	389	12	633	16	600
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY						
RESIDENTIAL HEAT PUMPS	15	353	13	408	11	382
INDUSTRIAL HEAT PUMPS	17	412	13	354	11	482
PROCESS HEAT RECOVERY	18	539	13	592	12	567
USE OF LOW PRESSURE EXHAUST STEAM	16	444	12	575	10	430
END PRODUCT EFFICIENCY						
CONSUMER APPLIANCES	14	379	12	417	11	291
MANUFACTURING EQUIPMENT	13	331	12	500	13	500
BUILDING INSULATION	16	500	12	600	11	445
ENERGY EFFICIENT BUILDINGS	16	500	13	638	10	520
TRANSPORTATION						
AUTOMOTIVE ENGINE	14	586	12	600	11	418
AUTOMOTIVE CHASSIS AND BODY	13	354	12	417	11	345
ELECTRIC / HYBRID VEHICLES	12	450	12	525	10	560
OTHER AUTOMOTIVE	4	275	4	450	5	160
RAIL TRANSPORTATION/EQUIPMENT	13	477	12	417	10	460
AIRCRAFT ENGINE AND AIRFRAME	13	508	12	358	9	500
PIPELINE TECHNOLOGIES	13	454	13	523	10	420
MARINE TRANSPORTATION / EQUIPMENT	13	408	12	400	10	430

TABLE 21B (continued)

	CONSUMER GOODS		GENERAL MACHINERY		LIGHT INDUSTRY	
	Resp.	Index	Resp.	Index	Resp.	Index
ELECTRIC POWER GENERATION						
GAS TURBINE COMBINED CYCLE	12	442	9	522	7	443
FUEL CELLS	13	715	8	538	9	700
MAGNETOHYDRODYNAMIC GENERATION	13	592	7	600	9	589
CRYOGENIC GENERATORS	13	546	6	417	7	414
TRANSMISSION AND DISTRIBUTION	13	508	10	590	7	600
LOW HEAD HYDROELECTRIC	13	569	10	630	7	557
FLUIDIZED BEDS	13	508	8	450	7	457
INDUSTRIAL COMBUSTION AND STEAM GENERATION						
COGENERATION	12	517	10	570	8	488
ATMOSPHERIC FLUIDIZED BED	14	471	9	467	8	488
COAL / OIL SLURRY	13	438	10	630	9	578
WASTE MATERIAL	13	592	12	775	11	718
INSTRUMENTATION AND CONTROL	13	300	8	313	7	414
ENERGY STORAGE						
PUMPED HYDRO STORAGE	13	308	9	544	7	429
COMPRESSED AIR STORAGE	13	338	8	388	7	429
THERMAL ENERGY STORAGE	13	485	9	522	9	667
BATTERIES	13	585	9	656	8	563
HYDROGEN GENERATION	14	571	10	660	8	500
OIL						
SECONDARY OIL RECOVERY	14	636	10	520	9	611
TERTIARY OIL RECOVERY	15	620	10	750	9	644
MATERIALS FOR ENHANCED OIL RECOVERY	14	614	9	656	9	644
HEAVY OIL	11	418	8	650	7	600
TAR SANDS	15	580	9	667	8	575
OIL SHALE	15	620	9	667	8	650
GEOLOGICAL ASSESSMENT TECHNIQUES	15	733	7	443	8	763
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	15	547	9	533	8	738

TABLE 21B (continued)

	CONSUMER GOODS		GENERAL MACHINERY		LIGHT INDUSTRY	
	Resp.	Index	Resp.	Index	Resp.	Index
GAS						
ENHANCED GAS RECOVERY	14	729	10	520	6	600
GEOPRESSURE METHANE	14	736	9	656	7	500
TIGHT SANDS	14	571	8	500	7	500
DEVONIAN SHALE	13	692	7	557	7	500
COAL						
PREPARATION	13	477	11	509	9	322
MINING	13	477	12	600	8	275
GASIFICATION	15	593	10	760	10	630
LIQUEFACTION	14	586	10	820	10	630
CHEMICAL FEEDSTOCKS	12	433	8	650	10	500
NUCLEAR						
FUEL PRODUCTION	14	779	11	691	10	660
FUEL SEPARATION	14	800	11	664	10	660
REPROCESSING	14	843	10	780	11	691
WASTE DISPOSAL	15	853	11	918	10	630
LIQUID METAL FAST BREEDER	13	831	10	750	10	690
OTHER BREEDER	5	620	-	-	6	583
REACTOR FOR INDUSTRIAL PROCESS USE	12	683	9	511	9	478
LIGHT WATER REACTORS	13	731	8	488	9	556
OTHER FISSION	6	633	-	-	6	583
FUSION	14	843	9	756	10	810
SOLAR AND OTHER RENEWABLE						
SOLAR PHOTOVOLTAIC	13	785	10	610	11	718
SOLAR THERMAL POWER GENERATION	13	692	11	700	9	667
SOLAR INDUSTRIAL PROCESS HEAT	14	614	10	610	9	589
HEATING AND COOLING	11	682	11	609	9	556
BIOMASS	13	669	9	689	8	625
MUNICIPAL SOLID WASTE	13	662	13	762	8	575
TIDAL	13	492	10	370	9	433
OCEAN THERMAL	14	621	10	310	9	511
GEOTHERMAL	14	586	10	540	11	527
WIND	13	569	11	545	9	533

TABLE 21C

Relative Importance Index for the Miscellaneous, Electric Power, and Building Materials Companies

CATEGORY / TECHNOLOGY	MISCELLANEOUS COMPANIES		ELECTRIC POWER		BUILDING MATERIALS	
	Resp.	Index	Resp.	Index	Resp.	Index
MANUFACTURING/PROCESS CHANGES						
RAW MATERIAL CHANGES	9	444	4	550	12	408
CHEMICAL / REFINING PROCESSES	8	500	6	650	5	420
NEW ENERGY SAVING PROCESSES	13	785	9	656	13	577
IMPROVED ENERGY SAVING PROCESSES	13	638	9	622	12	650
AIR CONDITIONING, HEAT PUMPS + HEAT RECOVERY						
RESIDENTIAL HEAT PUMPS	11	318	11	836	7	543
INDUSTRIAL HEAT PUMPS	12	367	7	829	8	563
PROCESS HEAT RECOVERY	11	682	10	560	8	675
USE OF LOW PRESSURE EXHAUST STEAM	10	760	10	640	6	250
END PRODUCT EFFICIENCY						
CONSUMER APPLIANCES	10	430	10	790	6	567
MANUFACTURING EQUIPMENT	11	464	7	657	6	350
BUILDING INSULATION	10	660	9	733	10	510
ENERGY EFFICIENT BUILDINGS	11	755	11	745	10	710
TRANSPORTATION						
AUTOMOTIVE ENGINE	12	667	8	525	6	783
AUTOMOTIVE CHASSIS AND BODY	9	433	6	433	4	525
ELECTRIC / HYBRID VEHICLES	10	500	9	733	4	675
OTHER AUTOMOTIVE	6	300	-	-	-	-
RAIL TRANSPORTATION/EQUIPMENT	10	530	8	663	4	675
AIRCRAFT ENGINE AND AIRFRAME	11	536	6	600	4	600
PIPELINE TECHNOLOGIES	9	522	8	375	4	600
MARINE TRANSPORTATION / EQUIPMENT	8	463	6	550	4	600

TABLE 21C (continued)

	MISCELLANEOUS COMPANIES		ELECTRIC POWER		BUILDING MATERIALS	
	Resp.	Index	Resp.	Index	Resp.	Index
ELECTRIC POWER GENERATION						
GAS TURBINE COMBINED CYCLE	10	630	10	850	6	633
FUEL CELLS	11	600	10	790	5	500
MAGNETOHYDRODYNAMIC GENERATION	8	538	10	670	7	657
CRYOGENIC GENERATORS	8	413	9	633	-	-
TRANSMISSION AND DISTRIBUTION	9	400	11	664	6	683
LOW HEAD HYDROELECTRIC	10	540	10	440	6	483
FLUIDIZED BEDS	11	609	10	760	8	688
INDUSTRIAL COMBUSTION AND STEAM GENERATION						
COGENERATION	9	722	9	633	8	650
ATMOSPHERIC FLUIDIZED BED	9	622	7	743	9	656
COAL / OIL SLURRY	10	470	7	700	9	689
WASTE MATERIAL	10	790	8	738	11	636
INSTRUMENTATION AND CONTROL	11	518	7	557	8	600
ENERGY STORAGE						
PUMPED HYDRO STORAGE	7	514	10	570	5	420
COMPRESSED AIR STORAGE	7	329	9	689	5	220
THERMAL ENERGY STORAGE	10	690	10	700	8	438
BATTERIES	9	622	9	833	8	650
HYDROGEN GENERATION	10	560	10	630	8	475
OIL						
SECONDARY OIL RECOVERY	8	700	7	87[illegible]	7	629
TERTIARY OIL RECOVERY	9	700	5	850	6	783
MATERIALS FOR ENHANCED OIL RECOVERY	7	700	7	87[illegible]	8	800
HEAVY OIL	6	550	5	583	4	675
TAR SANDS	7	657	7	700	6	633
OIL SHALE	8	663	8	813	8	575
GEOLOGICAL ASSESSMENT TECHNIQUES	7	657	7	700	7	829
OFFSHORE DRILLING + PRODUCTION TECHNIQUES	6	650	7	657	5	620

TABLE 21C (continued)

	MISCELLANEOUS COMPANIES		ELECTRIC POWER		BUILDING MATERIALS	
	Resp.	Index	Resp.	Index	Resp.	Index
GAS						
ENHANCED GAS RECOVERY	9	800	9	833	6	833
GEOPRESSURE METHANE	9	800	7	700	7	914
TIGHT SANDS	6	650	6	650	4	675
DEVONIAN SHALE	5	700	7	614	4	425
COAL						
PREPARATION	10	660	10	620	7	586
MINING	11	573	9	700	7	729
GASIFICATION	13	815	9	800	10	880
LIQUEFACTION	10	790	10	850	9	756
CHEMICAL FEEDSTOCKS	9	756	6	633	6	467
NUCLEAR						
FUEL PRODUCTION	8	813	9	800	5	740
FUEL SEPARATION	8	813	9	867	4	750
REPROCESSING	7	871	9	900	6	783
WASTE DISPOSAL	12	900	10	900	7	914
LIQUID METAL FAST BREEDER	9	833	13	954	4	750
OTHER BREEDER	-	-	6	850	-	-
REACTOR FOR INDUSTRIAL PROCESS USE	6	483	7	286	4	675
LIGHT WATER REACTORS	6	800	8	850	-	-
OTHER FISSION	-	-	5	760	-	-
FUSION	10	850	9	833	6	800
SOLAR AND OTHER RENEWABLE						
SOLAR PHOTOVOLTAIC	11	645	10	580	7	514
SOLAR THERMAL POWER GENERATION	10	610	10	580	8	538
SOLAR INDUSTRIAL PROCESS HEAT	12	650	8	625	7	414
HEATING AND COOLING	10	760	11	727	8	688
BIOMASS	12	700	9	600	8	538
MUNICIPAL SOLID WASTE	10	820	10	640	8	650
TIDAL	7	486	9	356	6	350
OCEAN THERMAL	7	486	10	420	5	220
GEOTHERMAL	6	550	9	567	6	483
WIND	9	600	11	473	5	220

TABLE 22

Opinion of Government Sponsorship Levels
For 192 Firms Responding

	Private Sector Percent Responding			
	NO	TL	AE	TM
Basic Research	16	31	36	17
Applied Research	12	33	39	16
Process Engineering	18	31	28	23
Pilot Plant	11	35	34	20
Demonstration Plant	16	28	36	20

	Public Sector Percent Responding			
	NO	TL	AE	TM
Basic Research	12	31	38	19
Applied Research	15	32	30	23
Process Engineering	12	39	34	15
Pilot Plant	15	29	35	21
Demonstration Plant	10	30	39	21

NO = No Opinion, TL = Too Little, AE = About Enough, TM = Too Much

APPENDIX E

List of Companies Contacted in

Year II Mail Survey*

*Because of subsidiaries who responded, there are 819 companies instead of 814. (Last five company names on list.)

LIST OF CORPORATIONS

A-T-O
ABBOTT LABORATORIES
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