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ABSTRACT

Presented are data on university researchers engaged in fossil fuel studies funded by the U.S. Department of Energy (DOE). This information relates to research personnel whose projects were active during 1977 and/or 1978. Frequency and percentage tabulations delineate person-months of graduate student, faculty, and staff research inputs by discipline and, in most cases, by subdiscipline. All data appear in a form that permits their use in estimating the impact on the labor force of changes in DOE research budgets. In addition, data collection methods are described and a preliminary assessment of the feasibility of expanding this procedure to compile similar work force data on all DOE-funded university research is given. (Author/WB)

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UNIVERSITY MANPOWER IN FOSSIL ENERGY RESEARCH AND DEVELOPMENT:

A Data Collection Feasibility Study

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UNIVERSITY MANPOWER IN FOSSIL ENERGY RESEARCH AND DEVELOPMENT:

A Data Collection Feasibility Study

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September 1979

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*Staff at Oak Ridge Associated Universities.

FOREWORD

This report presents data on the manpower engaged in DOE-funded fossil energy research in universities. It identifies man-months of graduate student, faculty, and staff inputs to this research effort by discipline, and in most cases also by subdiscipline. These statistics are presented for all DOE-funded fossil energy research conducted by universities as well as for subfields of fossil energy, e.g., coal and petroleum.

The data presented here come primarily from a review of [illegible] proposals and contracts in DOE files conducted during the summer of 1978. All of the projects examined were active during the 1977 and/or 1978 calendar years. While all the data come from this source, they were checked and classified by energy area using information from the Oak Ridge National Laboratory Energy Inventory, a compilation of energy research in progress. All data are presented in a form that permits their use in estimating the manpower implications of changes in DOE research budgets.

Fossil energy research is only a small part of all DOE research and development. Therefore, the method used to collect this data is described and a preliminary assessment of the feasibility of expanding the method to collect manpower data on all DOE-funded university research is made.

Norman Seltzer, Chief
Manpower Assessment
Office of Education, Business
and Labor Affairs

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INTRODUCTION

Throughout most of the 1950s and 1960s there was a concern in the United States about shortages of highly trained manpower. However, by the early 1970s, there were reports about unemployed engineers and physicists driving taxi cabs. These popular reports are supported by scholarly studies that indicate that the economic return to investments in higher education has indeed declined somewhat,[1] that there is a projected surplus of Ph.D.'s even in science and engineering,[2] and that an increasing proportion of new Ph.D.'s will be taking nonteaching jobs.[3] However, a general abundance of Ph.D.'s does not mean there will be no shortages or adjustment problems in specific occupations or subfields. The same analysts who documented the general surplus of high level manpower have also noted the possibility of shortages of specialized engineering and scientific manpower in fields affected by a major national research initiative, e.g., energy.[1,3] Energy research and development is cited as an area where there is potential for selective shortages for obvious reasons: The level of expenditures is very nigh and the composition of these expenditures (e.g., solar or nuclear) might experience abrupt changes.

There is growing interest in the employment impacts of alternative energy scenarios, and a number of studies are planned or are in progress. However, no studies have been identified which will estimate the impact of changes in research and development expenditures upon the employment of scientists and engineers and upon the occupational profile of the scientist and engineer work force. Alternative scenarios might have substantially different implications for energy research and development manpower, and it would seem worthwhile to specify the impact of these different scenarios on specific engineering and science specialties. However, at the present time researchers have only sketchy data on the occupational composition of the energy research and development work force, so it is impossible to determine the occupational impact of alternative scenarios.

This report describes a first attempt to collect such data for one specific energy research and development area. If expanded to a larger scale, the data collection effort described here would permit an employment impact analysis of various energy research scenarios. Furthermore, the data collected here are valuable for other purposes as well. For example, these data could be used to quantify the extent of graduate student involvement in all energy research and development conducted at universities.

REFERENCES

[1] Richard B. Freeman, *The Overeducated American*, New York: Academic Press, 1976.

[2] National Science Foundation, *Projections of Science and Engineering Doctorate Supply and Utilization*, Washington, D.C.: U.S. Government Printing Office, 1976, pp. 16, 22. Bureau of Labor Statistics, *Ph.D. Manpower: Employment, Demand, and Supply 1972-85*, Washington, D.C.: U.S. Government Printing Office, 1975, p. 11

[3] Allan M. Cartter, *Ph.D.'s and the Academic Labor Market*, New York: McGraw-Hill, 1976.

PART I: BACKGROUND AND DATA RESULTS

BACKGROUND

The manpower data on fossil energy research projects conducted at universities were collected through direct examination of contract files in the Department of Energy. Before deciding on this approach, however, the alternative of surveying universities and/or principal investigators was examined. It was concluded that the kind of information required was not available at any single central source on most university campuses. Surveying principal investigators to obtain information on the personnel working on their projects was also considered. A pretest indicated that, while feasible, such a survey would have a number of drawbacks. One was a low response rate. Many investigators expressed dismay at the thought of "another survey," especially when they felt that most of the information requested was available from their project monitors in Washington. Another drawback was that many principal investigators found it difficult to classify their projects by energy source. It was concluded that the only practical way to consistently classify energy research projects was to collect abstracts and classify them in a consistent manner. There are other drawbacks to a direct survey of researchers. For example, it is costly (especially when the cost of the respondent's time is considered).

The decision not to undertake a survey was also influenced by the existence of another survey that promised to be of some value, the Energy Inventory, conducted by Oak Ridge National Laboratory (ORNL), which attempts to gather basic information on all energy research projects in the United States. After receiving a promise of cooperation from the director of the Energy Inventory, it was decided that it would be most practical to develop the necessary basic information from this source and to supplement this with manpower data collected from contract files in DOE offices. There was little knowledge at the outset about how much manpower data would be available in contract files. The study was limited to fossil energy research for two reasons: (1) to obtian data in this specific field, and (2) to test the feasibility of this approach on a subset of all DOE-funded research.

THE DATA

Table 1 shows the basic data obtained from the research. The staffing patterns are cast in percentages to facilitate comparison among the energy research and development areas. For example, the table highlights the importance of chemistry and chemical engineering in research and development activities in the coal and petroleum areas and the much greater relative importance of the earth sciences in research and development activities in the natural gas and oil shales and tar sands areas. Most of the other tables in this report detail the statistics in Table 1.

DEFINITION OF ENERGY RESEARCH AND DEVELOPMENT AREAS

Each energy research project was classified using the subject category definitions developed by the Department of Energy for its computerized bibliographic information system.[1] Each project was assigned a primary code. In many instances, one or more secondary codes were also supplied. For example, a project's primary code might indicate that the research subject was materials, specifically ceramics, cermets, and refactories, but its secondary code might indicate that it dealt with coal and coal products, specifically coal gasification. The secondary classification was used in instances like this. In general, the primary subject code was used if it was one of the four fossil fuel categories constituting the columnar headings in Table 1, and the secondary category was used only if the primary category was not fossil fuel-related. In a few instances there were two secondary classifications, both fossil fuel. In these instances it was decided not to count the project twice but rather to assign half of the manpower and half of the budget to each project area, e.g., half to coal and half to petroleum. Thus, for example, Table 1 indicates that the petroleum data are based on a total of 19.5 projects.

Only about 85 percent of the projects for which data were collected were classified in one of the four fossil energy categories shown in Table 1. Those not classified as fossil energy research were projects that were either specifically classified in one of the other energy research areas (13 projects) or not classified at all (20 projects). The latter situation occurred in cases where the projects were not included in the ORNL Energy Inventory, the source for the subject classifications. The former situation occurred because some projects that seemed to be fossil energy research were,

Table 1. Staffing Patterns for Fossil Energy Research by Degree/Employment Field and Fossil Energy Area, 1977-1978

Degree/Employment Field	Coal and Coal Products	Petroleum	Natural Gas	Oil Shales and Tar Sands	Total, Fossil Energy
	Percent Distribution				
	Energy R&D Area				
Mathematical sciences	1.2	0	0	4.2	1.4
Physics	1.6	0	0	5.1	1.6
Chemistry	31.8	30.1	0	13.0	28.5
Earth sciences	5.7	19.5	99.2	39.1	12.4
Atmospheric and marine sciences	*	1.4	0	3.7	.6
Chemical engineering	35.1	44.8	0	11.4	32.4
All other engineering	22.5	3.8	0	12.7	18.6
Agricultural sciences	*	0	0	2.0	*
Biological sciences	2.0	*	0	4.5	2.2
Social sciences	*	0	0		*
Other fields	0	0	0	3.7	.5
Field not reported	1.7	0	.8	0	1.3
	100.0	100.0	100.0	100.0	100.0
Number of projects	135	19.5	3.5	18.	176
Dollar value of projects (in $000s)	$28,815	$3702	$419	$4450	$37,386

* Less than 0.5%.

NOTE: Column totals may not add to 100.0 percent because of rounding.

Source: United States Department of Energy.

in fact, not classified as such. Whether this was due to classification errors or not is a question which was not examined. Table 2 gives a breakdown of the number of research projects classified in each energy research area.

Table 2. Distribution of Research Projects by Energy R&D Area and Source of Data, 1977-1978

Energy R&D Areas	Source[a] 1	2	3	4	5	6	7	Total
Coal and coal products	114	4	0	0	7	2	8	135
Petroleum	1	12	0	1	4.5	1	0	19.5
Natural gas	0	3	0	0	.5	0	0	3.5
Oil shales and tar sands	3	12	0	0	2	1	0	18
Subtotal, fossil energy	118	31	0	1	14	4	8	176
Not fossil energy	4	1	1	5	0	0	2	13
Not classified	5	6	2	1	1	1	4	20
Total	127	38	3	7	15	5	14	209

[a]Sources of data:
1. DOE, Fossil Energy Program, Office of University Activities.
2. DOE, Fossil Energy Program: Oil, Gas, Shale, and In Situ Technology Division.
3. DOE, Fossil Energy Program, Magnetohydrodynamics Division.
4. DOE, Fossil Energy Program, Power Systems Division.
5. DOE, Biomedical and Environmental Research Division.
6. DOE, Environmental Control Technology Division.
7. DOE, Fossil Energy Program, Solid Fuel Mining and Preparation Division.

DEFINITION OF DEGREE/EMPLOYMENT FIELD

Data on the degree/employment field was sought for all persons engaged in the research projects examined. In most instances this information was available for Ph.D. level staff only; it was extracted from budget statements or vitae attached to project proposals. In some instances only the departmental affiliation of the researcher, e.g., associate professor, department of physics, was available. However, in most cases the degree field or an employment designation that referred to the role the Ph.D. was expected to play in the particular project was given. Since a description of the role played by the project staff was desired, the latter designation was chosen where available. The degree field was next in preference. The departmental affiliation was used in the few cases where no other information was available.

Only about one-fourth of the project proposals gave information on the field of specialization of the graduate students who were being proposed as part of the research team. The graduate field data were used when given. When not given, the graduate students were distributed among specialty fields in the same proportion as the faculty on the project. For example, if the faculty man-months were one-third chemistry and two-thirds chemical engineering, the graduate student man-months were assumed to follow the same pattern. In general this caused little harm in the averages generated because many projects had faculty from only one discipline, and it is most plausible that the faculty utilized graduate students from the same discipline. The field of specialization of undergraduate students was generally not available, and no attempt was made to produce an approximate distribution of undergraduate students by field of specialization.

There are several systems for classifying scientists and engineers by field. The system selected is that used by the National Academy of Sciences in its doctoral survey (Table 3).[2] Most of the staff with information on degree or employment fields had titles (on vitae or in the budget statement) that corresponded exactly with titles in Table 3. In most of the remaining cases, the documents reported a general degree employment field, e.g., "physics." In these instances, the researcher was assigned a title, e.g., "physics, general," from the list of titles in Table 3.

Only a few researchers were listed with specific subfield titles that did not match those in Table 3. They were all classified under the heading "other fields," but the title actually listed for these persons was also recorded. Fortunately, the total number of man-months accounted for by these researchers is only about one percent of the total. Since this one percent is made up of several different fields, no attempt was made to create new categories to describe them. The interested reader will find a listing of the specific fields affected in Appendix A.

TIME FRAME OF THE RESEARCH PROJECTS COVERED

The data presented here were collected during the summer of 1978. An attempt was made to include all active fossil energy projects. Inactive

Table 3. Degree and Employment Specialties List

MATHEMATICAL SCIENCES

000 - Algebra
010 - Analysis & Functional Analysis
020 - Geometry
030 - Logic
040 - Number Theory
052 - Probability
055 - Math, Statistics (see also 544, 670, 725, 729)
060 - Topology
080 - Computing Theory & Practice
082 - Operations Research (see also 477)
085 - Applied Mathematics
089 - Combinatorics & Finite Mathematics
091 - Physical Mathematics
098 - Mathematics, General
099 - Mathematics, Other*

ASTRONOMY

101 - Astronomy
102 - Astrophysics

PHYSICS

110 - Atomic & Molecular Physics
120 - Electromagnetism
130 - Mechanics
132 - Acoustics
134 - Fluids
135 - Plasma Physics
136 - Optics
138 - Thermal Physics
140 - Elementary Particles
150 - Nuclear Structure
160 - Solid State
198 - Physics, General
199 - Physics, Other*

CHEMISTRY

200 - Analytical
210 - Inorganic
215 - Synthetic Inorganic & Organometallic
220 - Organic
225 - Synthetic Organic & Natural Products
230 - Nuclear
240 - Physical
245 - Quantum
250 - Theoretical
255 - Structural
260 - Agricultural & Food
265 - Thermodynamics & Material Properties
270 - Pharmaceutical
275 - Polymers
280 - Biochemistry (see also 540)
285 - Chemical Dynamics
298 - Chemistry, General
299 - Chemistry, Other*

EARTH, ENVIRONMENTAL & MARINE SCIENCES

301 - Mineralogy, Petrology
305 - Geochemistry
310 - Stratigraphy, Sedimentation
320 - Paleontology
330 - Structural Geology
341 - Geophysics (Solid Earth)
350 - Geomorph., Glacial Geology
360 - Hydrology
370 - Oceanography
381 - Atmospheric Chemistry & Physics
382 - Atmospheric Dynamics
391 - Applied Geology, Geol. Engr., Econ. Geol.
388 - Environmental Sciences, General
389 - Environmental Sciences, Other*
397 - Marine Sciences, Other*
398 - Earth Sciences, General
399 - Earth Sciences, Other*

ENGINEERING

400 - Aeronautical & Astronautical
410 - Agricultural
415 - Biomedical
420 - Civil
430 - Chemical
435 - Ceramic
440 - Electrical
445 - Electronics
450 - Industrial, Manufacturing
455 - Nuclear
460 - Engineering Mechanics
465 - Engineering Physics
470 - Mechanical
475 - Metallurgy & Phys. Met. Engr.
477 - Operations Research, Systems (see also 082)
479 - Fuel Technology, Petrol Engr.
480 - Sanitary/Environmental
486 - Mining
497 - Materials Science Engr.
498 - Engineering, General
499 - Engineering, Other*

AGRICULTURAL SCIENCES

500 - Agronomy
501 - Agricultural Economics
502 - Animal Husbandry
504 - Fish & Wildlife
505 - Forestry
506 - Horticulture
507 - Soils & Soil Science
510 - Animal Sciences
511 - Phytopathology
517 - Food Science & Technology (see also 573)
518 - Agriculture, General
519 - Agriculture, Other*

MEDICAL SCIENCES

520 - Medicine & Surgery
522 - Public Health
523 - Veterinary Medicine
524 - Hospital Administration
527 - Parasitology
534 - Pathology
536 - Pharmacology
537 - Pharmacy
538 - Medical Sciences, General
539 - Medical Sciences, Other*

BIOLOGICAL SCIENCES

540 - Biochemistry (see also 280)
542 - Biophysics
543 - Biomathematics
544 - Biometrics, Biostatistics (see also 055, 670, 725, 729)
545 - Anatomy
546 - Cytology
547 - Embryology
548 - Immunology
550 - Botany
560 - Ecology
562 - Hydrobiology
564 - Microbiology & Bacteriology
566 - Physiology, Animal
567 - Physiology, Plant
569 - Zoology
570 - Genetics
571 - Entomology
572 - Molecular Biology
573 - Food Science & Technology (see also 517)
574 - Behavior/Ethology
578 - Biological Sciences, General
579 - Biological Sciences, Other*

PSYCHOLOGY

600 - Clinical
610 - Counseling & Guidance
620 - Developmental & Gerontological
630 - Educational
635 - School Psychology
641 - Experimental
642 - Comparative
643 - Physiological
650 - Industrial & Personnel
660 - Personality
670 - Psychometrics (see also 055, 544, 725, 729)
680 - Social
698 - Psychology, General
699 - Psychology, Other*

SOCIAL SCIENCES

700 - Anthropology
703 - Archeology
708 - Communications*
709 - Linguistics
710 - Sociology
720 - Economics (see also 501)
725 - Econometrics (see also 055, 544, 670, 729)
729 - Social Statistics (see also 055, 544, 670, 725)
740 - Geography
745 - Area Studies*
750 - Political Science, Public Administration
755 - International Relations
770 - Urban & Reg. Planning
775 - History & Phil. of Science
798 - Social Sciences, General
799 - Social Sciences, Other*

ARTS & HUMANITIES

841 - Fine & Applied Arts (including Music, Speech, Drama, etc.)
842 - History
843 - Philosophy, Religion, Theology
845 - Languages & Literature
846 - Other Arts and Humanities*

EDUCATION & OTHER PROFESSIONAL FIELDS

938 - Education

882 - Business Administration
883 - Home Economics
884 - Journalism
885 - Speech and Hearing Sciences
886 - Law, Jurisprudence
887 - Social Work
891 - Library & Archival Science
898 - Professional Field, Other*

899 - OTHER FIELDS*

*Identify the specific field in the space provided on the questionnaire.

Source: National Academy of Sciences.

projects were included if they were completed during 1977 or 1978. Many of the active projects had a three-year term and were not expected to be completed until 1979 or 1980. Thus, the time period covered by the projects presented here is fairly long.

Table 4 shows the distribution of the projects examined for this study by beginning and ending dates. Most of the projects began in 1976 or 1977 and were scheduled to end in 1978 or 1979. The average duration of the projects examined was two years, with a large number of projects (about 30 percent) lasting only a year or less, and an almost equal number lasting three years or more (see Figure 1).

Table 4. Distribution of Fossil Energy Research Projects by Beginning and Ending Dates, 1977-1978

Year	Projects Beginning	Projects Ending
1974	2	0
1975	20	0
1976	73	0
1977	98	26
1978	16	81
1979	0	86
1980	0	14
1981	0	2
Total	209	209

Source: United States Department of Energy.

REFERENCES FOR PART I

[1]U.S. Department of Energy, Office of Technical Information, *Energy Information Data Base--Subject Categories*, May 1978, TID-4584-R3 (NTIS).

[2]National Academy of Sciences and National Research Council, *Science, Engineering, and Humanities Doctorates in the United States, 1977 Profile*, Washington, D.C., National Academy of Sciences, 1978.

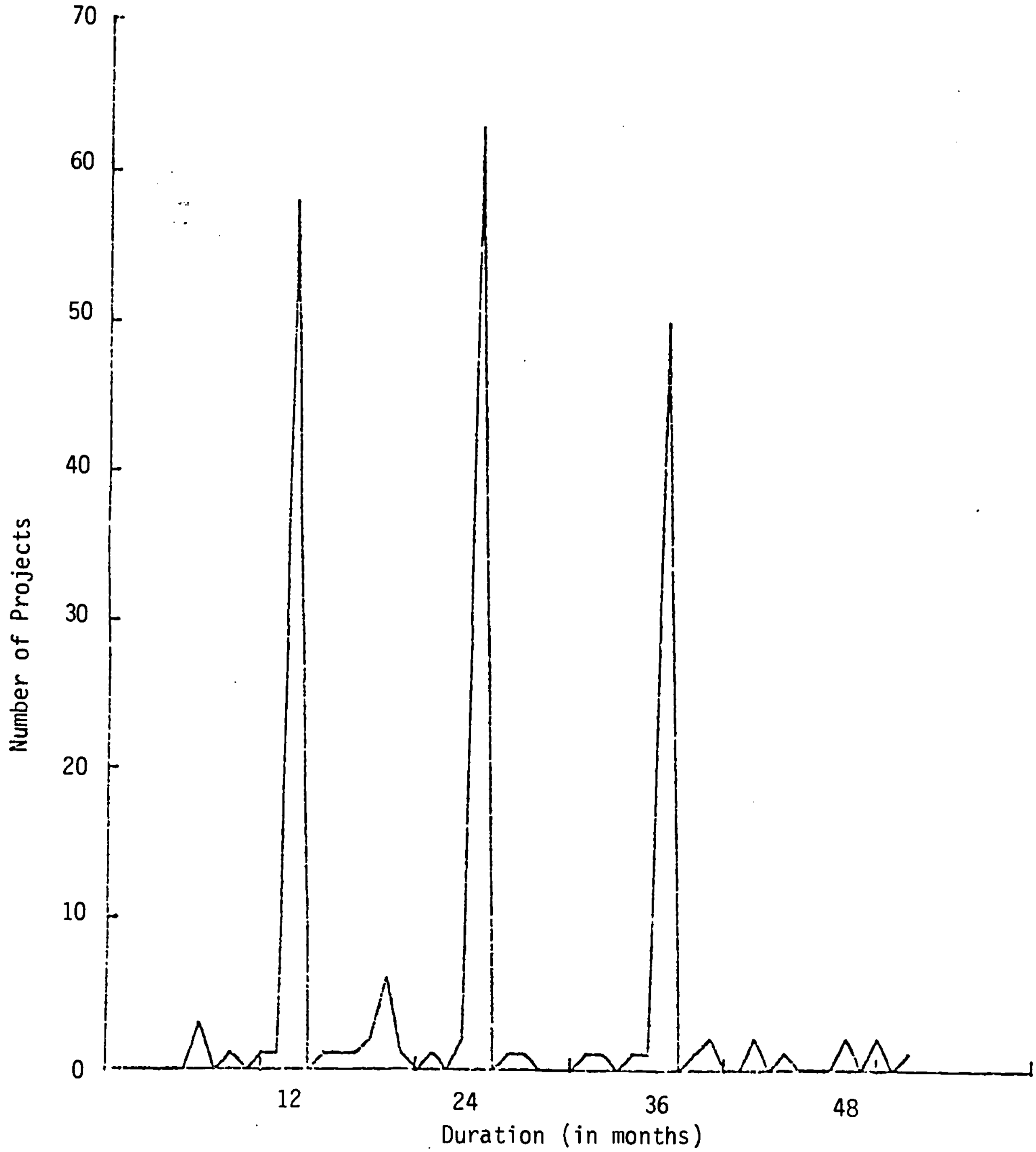

Figure 1. Duration of Fossil Energy Projects, 1977-1978

Source: United States Department of Energy.

STUDENT INVOLVEMENT

Students play a major role in DOE-funded fossil energy research. Graduate students provide 41.9 percent of all man-months; undergraduates account for another 4.9 percent. The total for all students, 46.8 percent of man-months, is more than twice as large as the man-months contributed by faculty (see Table 5).

STAFFING PATTERNS

Detailed staffing patterns for fossil energy research are shown in Table 6, which shows more detial in the categories of manpower than does Table 1. These data demonstrate the need for a disaggregate treatment of science and engineering fields. If one were to examine only the more aggregate statistics shown in Table 1, it would appear that the use of chemists is about the same in coal Research and Development as in petroleum Research and Development, i.e., about 30 percent of total manpower consists of chemists. However, the detail shown in Table 6 indicates there is probably little overlap between the types of chemists used in these two fields. The only overlap shown in Table 6 is that the field labeled "chemistry, general" is represented in the staffing patterns for both coal and petroleum research. As noted earlier, however, the chemists in this category are believed to be not generalists, but specialists whose subfields could not be specified from the data sources used.

Table 6 does not distinguish faculty from research associates or graduate students. Tables B-1 through B-5 in Appendix B do provide such additional detail.

For some purposes the energy Research and Development areas shown in Table 6 are too general. There is a variety of research included under each of the headings. The classification system used is quite disaggregate and allows, for example, estimates of separate staffing patterns for research on coal gasification, coal liquefaction, coal mining, etc. This more specialized classification could be done easily; the results would be constrained by small numbers. If there are only a few research projects in a subfield, the staffing patterns for that field must necessarily be used with caution.

Table 5. Faculty and Student Participation in Fossil Energy Research, 1977-1978

Energy Research and Development Area	Faculty	Research Associate[a]	Graduate Research Assistant	Undergraduate Research Assistant	Technician	Total
Coal and coal products						
Man-months	1798	2069	3974	442	1152	9435
Percent	19.1	21.9	42.1	4.7	12.2	100.0
Petroleum						
Man-months	276	204	585	132	71	1268
Percent	21.7	16.1	46.1	10.4	5.6	100.0
Natural gas						
Man-months	45	0	81	0	11	137
Percent	32.8	0	59.1	0	8.0	100.0
Oil shale and tar sands						
Man-months	550	360	511	27	13	1461
Percent	37.6	24.6	35.0	1.9	.9	100.0
Total, fossil energy						
Man-months	2669	2633	5151	601	1247	12,301
Percent	21.7	21.4	41.9	4.9	10.1	100.0

[a] Includes postdoctoral fellows.

NOTE: Percentages may not add to 100.0 because of rounding.

Source: United States Department of Energy.

Table 6. Staffing Patterns for Fossil Energy Research, by Degree/Employment Field and Energy R&D Area, 1977-1978

[Percent Distribution]

Degree/Employment Field	Coal and Coal Products	Petroleum	Natural Gas	Oil Shale and Tar Sands	Total Fossil Energy
Mathematical Sciences					
Statistics	0	0	0	4.2	0.6
Computer sciences	0.3	0	0	0	.2
Mathematics, general	.8	0	0	0	.6
Physics					
Plasma physics					
Solid state physics	.2	0	0	0	.1
Physics, general	1.0	0	0	5.1	1.4
Physics, other	.1	0	0	0	0
Chemistry					
Analytical chemistry	1.5	0	0	9.5	2.4
Inorganic chemistry	.8	0	0	2.0	.7
Organic chemistry	1.1	0	0	0	.8
Physical chemistry	7.8	0	0	0	5.9
Polymers chemistry		17.2	0	0	1.8
Chemistry, general	19.9	12.9	0	2.5	16.6
Chemistry, other	.4	0	0	0	.3
Earth, Atmospheric, and Marine Science					
Geochemistry	1.8	10.7	0	6.9	3.4
Stratigraphy, sedimentation	.2	0	0	0	.1
Structural geology	0	0	0	1.1	.1
Geology, general	2.6	6.6	99.2	28.7	7.7
Geophysics (solid earth)	0	0	0	1.6	.2
Oceanography	0	1.4	0	0	.1
Atmospheric physics and chemistry	0	0	0	3.7	.5
Earth science, other	.7	2.3	0	.8	.9

Table 6. Staffing Patterns for Fossil Energy Research, by Degree/Employment Field and Energy R&D Area, 1977-1978 (Cont'd)

[Percent Distribution]

Degree/Employment Field	Coal and Coal Products	Petroleum	Natural Gas	Oil Shale and Tar Sands	Total Fossil Energy
Engineering					
Aeronautical and astronautical engineering	2.3	0.7	0	0	1.8
Civil engineering	.8	0	0	1.0	.7
Chemical engineering	35.1	44.8	0	11.4	32.4
Ceramic engineering	.9	0	0	2.6	1.0
Electrical engineering	1.0	0	0	0	.8
Industrial and manufacturing engineering	.1	0	0	.1	.1
Nuclear engineering	.1	0	0	0	.1
Engineering mechanics	.8	0	0	1.5	.8
Mechanical engineering	5.7	0	0	.1	4.3
Metallurgy and physical metallurgy	2.8	.2	0	5.3	2.8
Fuel technology and petroleum engineering	3.0	1.2	0	0	2.4
Sanitary and environmental engineering	.5	0	0	2.1	.7
Mining engineering	.7	0	0	0	.5
Materials science engineering	2.4	.5	0	0	1.8
Engineering, general	0	1.2	0	0	.1
Engineering, other	.8	0	0	0	.6
Agriculture Sciences					
Agronomy	0	0	0	0.5	.1
Soils and soil science	.1	0	0	.2	.1
Agriculture, other	0	0	0	1.4	.2
Biological Sciences					
Botony	.1	0	0	.6	.2
Ecology	.5	0	0	3.9	.9
Microbiology and bacteriology	.4	0	0	.6	.4
Zoology	.3	0	0	0	.2
Biological sciences, general	.6	0	0	0	.4
Biological sciences, other	0	0.3	0	0	0

Table 6. Staffing Patterns for Fossil Energy Research, by Degree/Employment Field and Energy R&D Area, 1977-1978 (Cont'd)

[Percent Distribution]

Degree/Employment Field	Coal and Coal Products	Petroleum	Natural Gas	Oil Shale and Tar Sands	Total Fossil Energy
Social Sciences					
Economics	0	0	0	0	0.0
Geography	0.2	0	0	0	.2
Other fields	0	0	0	3.7	.5
Field not reported	1.7	0.1	0.8	0	1.3
Total	100.0	100.0	100.0	100.0	100.0

NOTE: Column totals may not add to 100.0 percent because of rounding.

Source: United States Department of Energy.

Another way of defining subfields of research is to examine the intersection of different research sets, which is how the category, "Environmental Aspects of Coal," was produced. Projects classified as "coal, environmental aspects" were combined with other projects that had dual classifications of "coal" and "environmental sciences." This produced a category of 11 projects. The staffing patterns for these 11 projects differ substantially from those of the other coal research projects (see Table 7). This fact suggests that if these data are used to test the manpower implications of alternative scenarios, care should be taken to avoid excessive aggregation of Research and Development areas; however, like projects should be combined.

MANPOWER INPUTS PER MILLION DOLLARS

These data are also useful for relating manpower levels to the cost of research. On the average, fossil energy projects required 329 man-months of input per million dollars of funding (see Table 8). Surprisingly, this varied little by energy Research and Development areas. The low was 327 for coal and coal products. The petroleum area, which makes relatively greater use of student manpower inputs, reported the high, 342 man-months per million dollars of input. There was considerably more difference in the man-months of faculty effort per million dollars of funding in the different energy areas, with a low of 62.4 for coal and a high of 123.6 for oil shale and tar sands, compared to 71.4 average. Similar differences exist in other types of manpower.

Together with staffing pattern data, these data can be used to project the manpower implications of proposed changes in research funding. For example, there is currently a rather tight market for chemical engineers in the United States. Suppose that DOE is considering a further expansion of research on coal and coal products, but officials wish to assess the impact of this change on chemical engineers. First, the price level would have to be adjusted since most of the data refer to projects that started in 1976 or 1977. Then, if the proposed increase in funding is stated in 1978 dollars, for example and the appropriate price level adjustment has been calculated to be 10 percent, the data in Table 8 can be deflated as follows: 100/110 = 0.9091. In this example, the total would be 297.6 man-months per million dollars (1978) budgeted (327.4 x 0.9091). Excluding the undergraduates and technicians, the total is reduced to 247.3 man-months. This total can then be distributed by field using the staffing patterns of Table 6 or Table B-1.

Table 7. Staffing Patterns: Environmental Aspects of Coal Research Compared to Other Coal Research, 1977-1978

Degree/Employment Field	Environmental Aspects of Coal	All Other Coal
Mathematical sciences		
Statistics	0	0
Computer sciences	0	0.3
Mathematics, general	0	.8
Physics		
Solid state physics	0	.2
Physics, general	0.4	1.0
Physics, other	0	.1
Chemistry		
Analytical chemistry	0	1.6
Inorganic chemistry	3.2	.6
Organic chemistry	6.1	.9
Physical chemistry	2.2	8.1
Polymers chemistry	0	0
Chemistry, general	7.4	20.5
Chemistry, other	0	.4
Earth, atmospheric, and marine scientist		
Geochemistry	0	1.9
Stratigraphy, sedimentation	0	.2
Structural geology	0	0
Geology, gneeral	4.2	2.5
Geophysics (solid earth)	.2	0
Oceanography	0	0
Atmospheric physics and chemistry	0	0
Earth science, other	0	.7
Engineering		
Aeronautical and astronautical engineering	0	2.4
Civil engineering	3.6	.6
Chemical engineering	28.0	35.5
Ceramic engineering	0	1.0
Electrical engineering	0	1.1
Industrial and manufacturing	0	0
engineering	0	.2
Nuclear engineering	0	.1
Engineering mechanics	0	.9
Mechanical engineering	0	6.0
Metallurgy and physical metallurgy	0	2.9
Fuel technology and petroleum engineering	0	3.1
Sanitary and environmental engineering	7.9	.2
Mining engineering	0	.7

Table 7. Staffing Patterns: Environmental Aspects of Coal Research Compared to Other Coal Research, 1977-1978 (Cont'd)

Degree/Employment Field	Environmental Aspects of Coal	All Other Coal
Engineering (Cont'd)		
Materials science engineering	0	2.5
Engineering, general	0	0
Engineering, other	0	.9
Agriculture sciences		
Agronomy	0	0
Soils and soil science	1.0	
Agriculture, other	0	0
Biological sciences		
Botony	2.5	0
Ecology	10.5	0
Microbiology and bacteriology	5.1	.2
Zoology	6.3	0
Biological sciences, general	11.0	0
Biological sciences, other	0	0
Social sciences		
Economics	.5	0
Geography	0	.2
Other fields	0	0
Field not reported	0	1.8
	100.0	100.0
Number of projects	11	124
Dollar value of projects (in $000s)	$1210	$27,606

Source: United States Department of Energy.

Table 8. Man-Months of Input per Million Dollars of Fossil Energy Research by Manpower Category and Fossil Energy Area, 1977-1978

Manpower Category	Energy R&D Area: Coal and Coal Products	Petroleum	Natural Gas	Oil Shale and Tar Sands	Total Fossil Energy
Faculty	62.4	74.4	106.2	123.6	71.4
Research associate (includes postdoctoral)	71.8	55.1	0	80.9	70.4
Graduate research assistant	137.9	158.0	194.6	114.8	137.8
Undergraduate research assistant	15.3	35.7	0	6.1	16.1
Technician	40.0	19.1	26.3	2.9	33.4
Total	327.4	342.3	327.1	328.3	329.1
Number of projects	135	19.5	3.5	18.0	176
Dollar value of projects (in $000s)	$28,816	$3702	$419	$4450	$37,387

Source: United States Department of Energy.

Doing so produces an estimate of 86.8 man-months of chemical engineers per million dollars (1978) of research funding. Thus, a $10 million increase would involve 868 man-months of chemical engineers including faculty, research associates, and graduate students.

Obviously, this example assumes that the staffing patterns of the past are a good guide for the future. If this were an actual projection rather than an illustration, it would be necessary to evaluate this assumption and make necessary adjustments.

PART 2: METHODOLOGICAL ASPECTS

LIMITATIONS OF THE PRESENT STUDY

This study was undertaken primarily to determine whether it would be feasible to collect needed manpower data from DOE contract records. In assessing the results of this experiment, both quantitative and qualitative aspects can be examined by answering the following questions: Was it possible to gather the data desired? Was the degree of bias or uncertainty of the data at a sufficiently low level? In answering both of these questions, it is necessary to keep in mind the purposes for which these data were sought: first, to provide data needed for studies of the manpower impact of alternative energy research scenarios, and second, to provide data on the amount and kind of student involvement in DOE-funded energy research.

Much of the data desired are available from contract records ("contract records" includes project proposals and vitae appended thereto). Generally speaking, these records contain excellent information on the number and fields of faculty. However, while the number of technicians involved and their total man-months of contribution are given, the specific field or category of the technician is generally not indicated. Likewise, participation by graduate and undergraduate students is indicated by man-months of involvement. However, while undergraduates are distinguished from graduate students, the undergraduate field of study is generally unavailable. This is not particularly serious because undergraduates provide only 4.9 percent of total man-months of input.

Data on the field of study of graduate students is also unavailable from contract files for the majority of the projects examined. Because it was deemed important to classify graduate student involvement by field, we constructed the field distribution by combining known and assumed data. That is, for the many projects that reported graduate student involvement but not field of study, the graduate student man-months were distributed in the same proportions and fields as the faculty on the same project. The assumption of proportional distribution need not hold true for all projects: If deviations from the assumed pattern tend to cancel each other out so that the assumption holds true for the average, then the graduate student staffing patterns presented here will be unbiased. However, it is known that current market conditions are very favorable for chemical engineers but not so favorable for chemists. As a result, it is reasonable to suppose that projects headed by chemical engineers sometimes use chemistry graduate students, but projects headed by chemists seldom, if ever, use chemical engineering graduate students. Anecdotal evidence implies that this is actually the case. Since the effect on aggregate statistics is believed to be small, however, no attempt has been made to adjust the data to account for this situation. Furthermore, a slight bias is certainly tolerable, especially given that it is diluted by the mixture of known data for some projects and assumed data for other projects. However, although the bias is thought to be small, no hard data upon which to base this judgment exists. The resulting uncertainty must be viewed as a limitation imposed by the use of contract data.

Another problem with the graduate student data is that some of the research associates reported in the contract files may be advanced graduate students. For example, some of the full-time research associates at universities are Ph.D. candidates who have finished all of their course work. If they are pursuing a degree at the same institution where they are working as a research associate, it can be argued that they should be counted as graduate students--at least for purposes of measuring the impact of DOE-funded research on the preparation of future research professionals.

Only persons specifically indicated as graduate students can be counted as graduate students. However, the large input of graduate student manpower (41.9 percent of total man-months) is noted. If one-third of the research associates are assumed to be graduate students (probably a high estimate), the percentage of total man-months supplied by graduate students would rise from 41.9 to 49.1 percent.

Another limitation inherent in the use of contract data is the fact that the actual staffing patterns of university research projects do not necessarily conform to the patterns stated explicitly in project proposals. Sometimes a project is funded at a level that is lower than the level originally proposed. When this happened, it was assumed that the reduction in manpower was proportionate to the reduction in funding. This seemed reasonable because the reductions were usually small, and most projects were funded at the level proposed by the university. However, there is certainly the possibility of some error on this account. Perhaps more important, however, is the likelihood that actual staffing patterns differ somewhat from planned staffing patterns. To the extent that this is true, it is apparent that the planned rather than the actual staffing patterns were measured.

Another methodological limitation in this study is that it was not always possible to find disaggregate data on degree/employment field. Persons for whom a specialty was indicated in the contract records (e.g., an analytical chemist) were always classified in a detailed category which recorded their specialty. However, persons given more general field designations in the contract records (e.g., chemist) were of necessity classified in a less detailed category. Persons listed in the records with such a general field designation were classified under headings such as "chemistry, general." This problem varies considerably by field: For instance, it is not a serious problem among engineering disciplines; but among chemistry disciplines it is. Table 9 presents data that help to put this problem in context. It compares data collected from contract files for this study with data collected by the National Academy of Sciences (NAS) via a direct survey of science and engineering doctorates. The NAS data show how many of the doctoral level chemists, physicists, engineers, etc., classified themselves in general categories when asked to choose the category that best describes their work. Data for this study were classified according to the same classification system. It would be unusual for the two sets to be identical under any circumstances because of differences in the populations described. Nevertheless, the NAS data provide a reference point indicating an average level of general responses.

Table 9 shows that the problem is negligible among engineers. Only 0.5 and 1.4 percent, respectively, of all engineers were classified in the categories "engineering, general" or "engineering, other." This means that the problem is not too serious in the data from contract files because engineers make up slightly more than half of all manpower inputs. In contrast, these same contract file data show that 53.2 percent of all chemistry man-months were contributed by chemists who were classified "chemistry, general." The NAS data show only 5.7 percent in the same category.

All of the data presented here are expressed in terms of man-months of involvement. These data, by themselves, can not provide an accurate count of the number of different persons involved in fossil energy research and development at universities. However, because the names of researchers in contract files were recorded it would be possible to tabulate the number of different persons involved, at least in the faculty and research associate categories.

Table 9. General and Other Field Designations as a Percentage of All Reported Ph.D.'s in Selected Fields, 1977-1978

	Faculty Data from This Study[1]	All Ph.D.'s, NAS Data[2]
Physics, general	94.1	17.1
Physics, other	0	11.3
Chemistry, general	53.2	5.7
Chemistry, other	1.3	7.9
Earth science, general	89.6	15.1
Earth science, other	1.9	18.5
Engineering, general	.5	1.7
Engineering, other	1.4	4.5

[1]Faculty data from Appendix B, Table B-5.

[2]NAS data from National Academy of Science, *Science Engineering and Humanities Doctorates in the United States--1977 Profile*, Washington, D.C., National Academy of Sciences, 1978.

With respect to graduate students, the data on the number of different persons involved are simply not available from contract files. Although some projects do refer to a specific number of students, there is no reason to believe that these are accurate estimates. Other projects refer only to graduate student man-months. The only practical way to get estimates of the number of graduate students involved is to make assumptions or independent estimates regarding man-months per graduate student.

EXPANDING THIS RESEARCH

It appears that it would be feasible to expand this study to cover all DOE-funded energy research in universities, and probably to all DOE-funded energy research. However, such an expansion would involve classified research projects. The difficulties inherent in working with classified material were not experienced in the course of this pilot study. Therefore, discussion is confined to university research projects.

In at least one respect this project would have been easier if it had been on a larger scale from the beginning. Information on fossil energy research projects was gathered in some DOE offices that held records on a wide variety of energy research, so that those projects that were fossil energy-related had to be sorted from others. If the study were duplicated on all energy research, such sorting would not be necessary. Also, some fossil energy projects were undoubtedly missed because records were held in offices not visited. This, too, would be less likely if the project were conducted on a broader scale.

The feasibility of expanding this study on a wide scale depends in part on the continued availability of information su as that obtained from the Energy Inventory. Although Energy Inventory project at Oak Ridge National Laboratory has been cancelled, a similar function is continued by DOE's Technical Information Center in Oak Ridge. The Department of Energy does not conduct a survey as such, but now requires all principal investigators to complete a form containing the basic information formerly collected by the Energy Inventory. Furthermore, this is done as a regular part of the grant or contract process. Thus, the basic information obtained from the Energy Inventory will be available regularly.

It will be no small undertaking to collect this kind of data for all DOE-funded energy research. Since the number of DOE-funded research projects in universities is more than 10 times as large as the number examined for this study, it can be roughly estimated that collecting data similar to that recorded for this study would take about one man-year of effort. Since such data becomes obsolete in a short period of time, it would have to be collected at least every two or three years if researchers are to have confidence in the results.

Because of the magnitude of the data collection effort, inquiries should be made to determine whether it is feasible to have the necessary manpower information collected by the Technical Information Center in the same manner that it will be using to collect other basic data on research projects in process.

APPENDIX A - FIELD TITLES NOT COINCIDING WITH TITLES IN TABLE 3

Title	Number	Manpower Category
Gas engineering	1	Principal investigator
Propulsion fluid dynamics	1	Research associate
Paleobotany	2	Principal investigators
Petographer	1	Faculty/staff associate
	1	Graduate assistant
Aerodynamics	1	Principal investigator
Range science	1	Principal investigator
	1	Faculty/staff associate
	1	Research associate
	1	Graduate assistant
Range ecology	1	Principal investigator
	1	Graduate assistant
Plant ecology	1	Principal investigator
	2	Faculty/staff associates
	1	Research associate
	1	Graduate assistant
Atmospheric science	2	Principal investigators
	1	Research associate
	2	Graduate assistants
Geological sciences	2	Principal investigators
Data processor	1	Faculty/staff associate
	1	Research associate
	1	Graduate assistant
Fishery biology	1	Faculty/staff associate
Spectrochemist	1	Research associate

APPENDIX B - DETAILED STAFFING PATTERN DATA

LIST OF TABLES IN APPENDIX B

Page

Table B-1. Staffing Patterns by Field and Manpower Category for R&D on Coal and Coal Products, 1977-1978

Field[a]	Faculty/Staff		Research Associate		Graduate Student		Total	
	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4.8	0.3	11.3	0.5	9.7	0.2	25.8	0.3
3	6.6	0.4	24.0	1.2	30.0	0.8	60.6	0.8
5	2.7	0.2	0.0	0.0	12.0	0.3	14.7	0.2
6	43.0	2.4	9.0	0.4	24.1	0.6	76.1	1.0
7	0.0	0.0	4.5	0.2	0.0	0.0	4.5	0.1
8	36.0	2.0	80.2	3.9	0.0	0.0	116.2	1.5
9	17.9	1.0	12.0	0.6	31.1	0.8	61.0	0.8
10	23.4	1.3	10.2	0.5	53.9	1.4	87.5	1.1
11	113.2	6.3	243.7	11.8	256.1	6.4	613.0	7.8
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	278.3	15.5	596.5	28.8	683.1	17.2	1557.9	19.9
14	7.4	0.4	13.7	0.7	12.0	0.3	33.1	0.4
15	30.9	1.7	40.9	2.0	68.6	1.7	140.4	1.8
16	0.0	0.0	0.0	0.0	12.0	0.3	12.0	0.2
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	97.1	5.4	20.1	1.0	85.9	2.2	203.1	2.6
20	0.5	0.0	0.0	0.0	0.1	0.0	0.6	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	9.0	0.5	14.6	0.7	30.2	0.8	53.8	0.7
25	31.7	1.8	15.8	0.8	134.4	3.4	181.9	2.3
26	9.2	0.5	26.2	1.3	24.3	0.6	59.7	0.8
27	663.3	36.9	631.4	30.5	1457.5	36.7	2752.2	35.1
28	12.5	0.7	24.0	1.2	36.0	0.9	72.5	0.9
29	21.0	1.2	4.5	0.2	55.5	1.4	81.0	1.0

[a]For definition of field code numbers see listing at end of this Appendix.

Table B-1. Staffing Patterns by Field and Manpower Category for R&D on Coal and Coal Products, 1977-1978 (Cont'd)

	Faculty/Staff		Research Associate		Graduate Student		Total	
Field[a]	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
30	5.2	0.3	0.0	0.0	6.0	0.2	11.2	0.1
31	0.0	0.0	9.6	0.5	0.0	0.0	9.6	0.1
32	7.6	0.4	24.0	1.2	33.0	0.8	64.6	0.8
33	125.7	7.0	12.6	0.6	305.1	7.7	443.4	5.7
34	22.3	1.2	84.8	4.1	109.2	2.7	216.3	2.8
35	45.4	2.5	56.4	2.7	131.6	3.3	233.4	3.0
36	17.2	1.0	0.0	0.0	25.8	0.6	43.0	0.5
37	17.6	1.0	3.3	0.2	30.3	0.8	51.2	0.7
38	42.8	2.4	12.0	0.6	131.2	3.3	186.0	2.4
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	17.5	1.0	24.0	1.2	24.8	0.6	66.3	0.8
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	1.2	0.1	0.0	0.0	2.8	0.1	4.0	0.1
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	3.0	0.2	0.0	0.0	7.0	0.2	10.0	0.1
45	11.8	0.7	15.5	0.7	14.0	0.4	41.3	0.5
46	10.0	0.6	0.0	0.0	22.0	0.6	32.0	0.4
47	5.9	0.3	12.0	0.6	7.0	0.2	24.9	0.3
48	13.0	0.7	0.0	0.0	30.3	0.8	43.3	0.6
49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.6	0.0	0.0	0.0	1.4	0.0	2.0	0.0
51	3.6	0.2	0.0	0.0	13.5	0.3	17.1	0.2
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	39.0	2.2	31.8	1.5	62.5	1.6	133.3	1.7
Total	1797.9	100.0	2068.6	100.0	3974.0	100.0	7840.5	100.0

[a]For definition of field code numbers see listing at end of this Appendix.

Source: United States Department of Energy.

Table B-2. Staffing Patterns by Field and Manpower Category for R&D on Petroleum, 1977-1978

	Faculty/Staff		Research Associate		Graduate Student		Total	
Field[a]	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	39.1	14.2	0.0	0.0	144.0	24.6	183.1	17.2
13	14.9	5.4	52.7	25.8	69.3	11.8	136.9	12.9
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	50.7	18.4	21.0	10.3	42.1	7.2	113.8	10.7
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	54.0	19.6	0.0	0.0	15.9	2.7	69.9	6.6
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	5.2	1.9	4.8	2.4	4.8	0.8	14.8	1.4
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	24.0	11.8	0.0	0.0	24.0	2.3
25	2.9	1.1	0.0	0.0	4.4	0.8	7.3	0.7
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	91.0	33.0	95.4	46.8	290.6	49.7	477.0	44.8
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.1	0.0	0.0	0.0	0.2	0.0	0.3	0.0

[a]For definition of field code numbers see listing at end of this Appendix.

Table B-2. Staffing Patterns by Field and Manpower Category for R&D on Petroleum, 1977-1978 (Cont'd)

	Faculty/Staff		Research Associate		Graduate Student		Total	
Field[a]	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	2.4	0.9	0.0	0.0	0.0	0.0	2.4	0.2
35	6.3	2.3	0.0	0.0	6.0	1.0	12.3	1.2
36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	1.0	0.4	1.9	0.9	2.5	0.4	5.4	0.5
39	6.0	2.2	3.0	1.5	4.0	0.7	13.0	1.2
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	1.0	0.4	1.2	0.6	1.2	0.2	3.4	0.3
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	1.0	0.4	0.0	0.0	0.0	0.0	1.0	0.1
Total	275.6	100.0	204.0	100.0	585.0	100.0	1064.6	100.0

[a]For definition of field code numbers see listing at end of this Appendix.

Source: United States Department of Energy.

Table B-3. Staffing Patterns by Field and Manpower Category for R&D on Natural Gas, 1977-1978

	Faculty/Staff		Research Associate		Graduate Student		Total	
Field[a]	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	43.5	97.8	0.0	0.0	81.5	100.0	[illegible]	99.2
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For definition of field code numbers see listing at end of this Appendix.

Table B-3. Staffing Patterns by Field and Manpower Category for R&D on Natural Gas, 1977-1978 (Cont'd)

Field[a]	Faculty/Staff		Research Associate		Graduate Student		Total	
	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	1.0	2.2	0.0	0.0	0.0	0.0	1.0	0.8
Total	44.5	100.0	0.0	0.0	81.5	100.0	126.0	100.0

[a]For definition of field code numbers see listing at end of this Appendix.

Source: United States Department of Energy.

Table B-4. Staffing Patterns by Field and Manpower Category for R&D on Oil Shales and Tar Sands, 1977-1978

	Faculty/Staff		Research Associate		Graduate Student		Total	
Field[a]	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
1	36.0	6.5	24.0	6.7	0.0	0.0	60.0	4.2
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	72.0	20.0	0.0	0.0	72.0	5.1
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	36.0	6.5	98.4	27.3	0.0	0.0	134.4	9.5
9	3.4	0.6	0.0	0.0	11.1	2.2	14.5	1.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	21.0	3.8	12.0	3.3	3.0	0.6	36.0	2.5
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	52.4	9.5	24.0	6.7	21.0	4.1	97.4	6.9
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	15.4	2.8	0.0	0.0	0.0	0.0	15.4	1.1
19	231.7	42.1	48.0	13.3	128.0	25.1	407.7	28.7
20	22.5	4.1	0.0	0.0	0.0	0.0	22.5	1.6
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	4.1	0.7	3.6	1.0	45.0	8.8	52.7	3.7
24	0.0	0.0	12.0	3.3	0.0	0.0	12.0	0.8
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	8.1	1.5	0.0	0.0	5.6	1.1	13.7	1.0
27	47.5	8.6	0.0	0.0	114.0	22.3	161.5	11.4
28	8.7	1.6	0.0	0.0	28.4	5.6	37.1	2.6
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For definition of field code numbers see listing at end of this Appendix.

Table B-4. Staffing Patterns by Field and Manpower Category for R&D on Oil Shales and Tar Sands, 1977-1978 (Cont'd)

	Faculty/Staff		Research Associate		Graduate Student		Total	
Field[a]	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
30	1.0	0.2	0.0	0.0	0.7	0.1	1.7	0.1
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	9.1	1.7	0.0	0.0	12.2	2.4	21.3	1.5
33	1.0	0.2	0.0	0.0	0.7	0.1	1.7	0.1
34	18.7	3.4	0.0	0.0	56.3	11.0	75.0	5.3
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	2.6	0.5	18.0	5.0	9.0	1.8	29.6	2.1
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	2.0	0.4	0.0	0.0	4.7	0.9	6.7	0.5
42	1.0	0.2	0.0	0.0	2.3	0.5	3.3	0.2
43	2.5	0.5	12.0	3.3	5.8	1.1	20.3	1.4
44	2.5	0.5	0.0	0.0	5.8	1.1	8.3	0.6
45	16.5	3.0	0.0	0.0	38.5	7.5	55.0	3.9
46	2.5	0.5	0.0	0.0	5.8	1.1	8.3	0.6
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52	4.0	0.7	36.0	10.0	13.0	2.5	53.0	3.7
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	550.2	100.0	360.0	100.0	510.9	100.0	1421.1	100.0

[a]For definition of field code numbers see listing at end of this Appendix.

Source: United States Department of Energy.

Table B-5. Staffing Patterns by Field and Manpower Category for R&D on Fossil Energy*, 1977-1978

	Faculty/Staff		Research Associate		Graduate Student		Total	
Field[a]	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
1	36.0	1.3	24.0	0.9	0.0	0.0	60.0	0.6
2	4.8	0.2	11.3	0.4	9.7	0.2	25.8	0.2
3	6.6	0.2	24.0	0.9	30.0	0.6	60.6	0.6
5	2.7	0.1	0.0	0.0	12.0	0.2	14.7	0.1
6	43.0	1.6	81.0	3.1	24.1	0.5	148.1	1.4
7	0.0	0.0	4.5	0.2	0.0	0.0	4.5	0.0
8	72.0	2.7	178.6	6.8	0.0	0.0	250.6	2.4
9	21.3	0.8	12.0	0.5	42.2	0.8	75.5	0.7
10	23.4	0.9	10.2	0.4	53.9	1.0	87.5	0.8
11	113.2	4.2	243.7	9.3	256.1	5.0	613.0	5.9
12	39.1	1.5	0.0	0.0	144.0	2.8	183.1	1.8
13	314.2	11.8	661.2	25.1	755.4	14.7	1730.8	16.6
14	7.4	0.3	13.7	0.5	12.0	0.2	33.1	0.3
15	134.0	5.0	85.9	3.3	131.7	2.6	351.6	3.4
16	0.0	0.0	0.0	0.0	12.0	0.2	12.0	0.1
18	15.4	0.6	0.0	0.0	0.0	0.0	15.4	0.1
19	426.3	16.0	68.1	2.6	311.3	6.0	805.7	7.7
20	23.0	0.9	0.0	0.0	0.1	0.0	23.1	0.2
21	5.2	0.2	4.8	0.2	4.8	0.1	14.8	0.1
22	4.1	0.2	3.6	0.1	45.0	0.9	52.7	0.5
24	9.0	0.3	50.6	1.9	30.2	0.6	89.8	0.9
25	34.6	1.3	15.8	0.6	138.8	2.7	189.2	1.8
26	17.3	0.6	26.2	1.0	29.9	0.6	73.4	0.7
27	801.8	30.1	726.8	27.6	1862.1	36.1	3390.7	32.4
28	21.2	0.8	24.0	0.9	64.4	1.3	109.6	1.0
29	21.1	0.8	4.5	0.2	55.7	1.1	81.3	0.8

[a]For definition of field code numbers see listing at end of this Appendix.

*Summary of Tables B-1 through B-4.

Table B-5. Staffing Patterns by Field and Manpower Category for R&D on Fossil Energy, 1977-1978 (Cont'd)

	Faculty/Staff		Research Associate		Graduate Student		Total	
Field[a]	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent	Man-Months	Percent
30	6.2	0.2	0.0	0.0	6.7	0.1	12.9	0.1
31	0.0	0.0	9.6	0.4	0.0	0.0	9.6	0.1
32	16.7	0.6	24.0	0.9	45.2	0.9	85.9	0.8
33	126.7	4.7	12.6	0.5	305.8	5.9	445.1	4.3
34	43.4	1.6	84.8	3.2	165.5	3.2	293.7	2.8
35	51.7	1.9	56.4	2.1	137.6	2.7	245.7	2.4
36	19.8	0.7	18.0	0.7	34.8	0.7	72.6	0.7
37	17.6	0.7	3.3	0.1	30.3	0.6	51.2	0.5
38	43.8	1.6	13.9	0.5	133.7	2.6	191.4	1.8
39	6.0	0.2	3.0	0.1	4.0	0.1	13.0	0.1
40	17.5	0.7	24.0	0.9	24.8	0.5	66.3	0.6
41	2.0	0.1	0.0	0.0	4.7	0.1	6.7	0.1
42	2.2	0.1	0.0	0.0	5.1	0.1	7.3	0.1
43	2.5	0.1	12.0	0.5	5.8	0.1	20.3	0.2
44	5.5	0.2	0.0	0.0	12.8	0.2	18.3	0.2
45	28.3	1.1	15.5	0.6	52.5	1.0	96.3	0.9
46	12.5	0.5	0.0	0.0	27.8	0.5	40.3	0.4
47	5.9	0.2	12.0	0.5	7.0	0.1	24.9	0.2
48	13.0	0.5	0.0	0.0	30.3	0.6	43.3	0.4
49	1.0	0.0	1.2	0.0	1.2	0.0	3.4	0.0
50	0.6	0.0	0.0	0.0	1.4	0.0	2.0	0.0
51	3.6	0.1	0.0	0.0	13.5	0.3	17.1	0.2
52	4.0	0.1	36.0	1.4	13.0	0.3	53.0	0.5
53	41.0	1.5	31.8	1.2	62.5	1.2	135.3	1.3
Total	2668.2	100.0	2632.6	100.0	5151.4	100.0	10452.1	100.0

[a]For definition of field code numbers see listing at end of this Appendix.

Source: United States Department of Energy.

List of Field Titles

Mathematical sciences

1. Mathematical statistics
2. Computer sciences
3. Mathematics, general

Physics

4. Plasma physics
5. Solid state physics
6. Physics, general
7. Physics, other

Chemistry

8. Analytical chemistry
9. Inorganic chemistry
10. Organic chemistry
11. Physical chemistry
12. Polymers chemistry
13. Chemistry, general
14. Chemistry, other

Earth, atmospheric, and marine scientist

15. Geochemistry
16. Stratigraphy, sedimentation
18. Structural geology
19. Geology, general
20. Geophysics, (solid earth)
21. Oceanography
22. Atmospheric physics and chemistry
24. Earth science, other

Engineering

25. Aeronautical and astronautical engineering
26. Civil engineering
27. Chemical engineering
28. Ceramic engineering
29. Electrical engineering
30. Industrial and manufacturing engineering
31. Nuclear engineering
32. Engineering mechanics
33. Mechanical engineering
34. Metallurgy and physical metallurgy

Engineering (Cont'd)

35. Fuel technology and petroleum engineering
36. Sanitary and environmental engineering
37. Mining engineering
38. Materials science engineering
39. Engineering, general
40. Engineering, other

Agriculture sciences

41. Agronomy
42. Soils and soil science
43. Agriculture, other

Biological sciences

44. Botony
45. Ecology
46. Microbiology and bacteriology
47. Zoology
48. Biological sciences, general
49. Biological sciences, other

Social sciences

50. Economics
51. Geography
52. Other fields

53. Field not reported

NOTE: This is an abridged version of Table 3. Those titles listed in Table 3 but not here are for fields not reported by the researchers we studied.