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ABSTRACT

This publication is the result of a study commissioned by the Energy Research and Development Administration (ERDA) to design a manpower information system as indicated by the title. This study is designed to help ERDA (now the Department of Energy) meet its responsibility of helping to assure an adequate supply of manpower for the accomplishment of energy research and development programs. Contents include: (1) Summary of recommendations; (2) The need for a comprehensive energy manpower information system; (3) Scope and definitions of components of the manpower information system; (4) Rationale and analytical framework; (5) Elements of a comprehensive manpower information system; (6) Application and utilization of the elements of the manpower assessment information system; and (7) The current manpower situation. Appendices include: (1) Taxonomies for the classification of data on energy research and development manpower; (2) Data sources relevant to energy research, development and demonstration manpower; (3) Bibliography; and (4) List of persons interviewed. (MR)

HCP/U6046-01

Manpower for Energy Research

Design of a Comprehensive Manpower Information System for Energy Research, Development and Demonstration

February 1978

Prepared for
U.S. Department of Energy
Assistant Secretary for Intergovernmental and Institutional Relations
Office of Education, Business and Labor Affairs

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PREFACE

When the oil embargo was imposed on this country in 1973, the American public became aware of what many analysts had long known: an inexhaustible, cheap and ever dependable energy supply could not be taken for granted. New sources of energy had to be found and developed. Old sources had to be looked at with fresh ideas on how they could better meet our needs. And all sources had to be stretched by more efficient ways of production, transmission and use that would lower the rising rates of energy consumption that had characterized American life for many years.

Much of what has to be done depends on the success of science and technology in finding alternative supplies of energy and new ways of using all forms of energy more effectively. The Congress has increased the financial support of research, development and demonstration efforts, and RD&D programs are being developed along many lines aimed at improving the energy situation. And this means that many highly trained scientists, engineers and technicians have had to be recruited.

The critical role of highly-trained workers was recognized in the organic law that created the Energy Research and Development Administration, and that now has become part of the responsibility and authority of the new Department of Energy. That law specified the responsibility of

> ...helping to assure an adequate supply of manpower for the accomplishment of energy research and development programs, by sponsoring and assisting in education and training activities in institutions of higher education, vocational schools and other institutions, <u>and by assuring the collection, analysis, and dissemination of necessary manpower supply and demand data</u>. (P.L. 93-438, Title I, Subsection 103 (10); emphasis supplied.)

To aid in discharging this responsibility for data collection, analysis and dissemination, Kramer Associates, Incorporated (KAI) submitted a proposal to study the design of a manpower information system to the Manpower Assessment Office in the Office of University Relations of the Energy Research and Development Agency. ERDA subsequently commissioned KAI to design a national information system on highly-skilled manpower engaged in energy-related research, development, and demonstration programs.

Work began on this study in the Spring of 1977. On October 1, ERDA's functions were transferred to the new Department of Energy, which has broader responsibilities. The need for information on RD&D manpower is crucial enough to warrant implementation of the information system described in this report at the earliest possible time, while at the same time the potential can be considered for adapting this system to the broader needs for information on all of the manpower required to complete the mission of the Department.

Kramer Associates, Inc. is glad to acknowledge the cooperation of many members of the Department of Energy staff, including Norman Seltzer, Chief of the Manpower Assessment Office, June S. Chewning of the staff of the Office, Arthur Saltzman, Consultant, and the many officials we interviewed, who are listed in Appendix D, together with representatives of other organizations, for whose cordial cooperation in providing information we are grateful.

The Kramer Associates staff who worked on the project are Robert W. Cain, Thomas J. Mills, Herman Travis, and Harold Goldstein, Principal Investigator. Dr. John Enoch Johnson served as a consultant on scientific matters and conducted interviews with officials of the DOE and of research laboratories. Mary Ann Power-Boyd was Research Assistant.

Leo Kramer
President
Kramer Associates, Inc.

CONTENTS

SUMMARY OF RECOMMENDATIONS

I. GENERAL RECOMMENDATIONS

1. The availability of scientific, technical and skilled manpower for Department of Energy research, development and demonstration programs cannot be taken for granted. DOE should make a positive effort to assure this availability and should develop the capacity to monitor the present manpower situation and anticipate future problems.

2. The present study is confined to energy RD&D manpower, only a part of the DOE's broader manpower interests. While a program to implement the manpower information system for RD&D should be initiated now, a study looking toward broadening the scope of the system described here to include all manpower needed for DOE's programs should be undertaken.

3. A comprehensive manpower information system for energy research and development should take advantage of existing data sources where possible. In the course of this study more than one hundred data sources were reviewed, and 66 were selected as relevant to DOE's needs. New data sources should be developed only if existing sources cannot meet the needs. DOE will have to take an active role to assure that its special requirements are met by the agencies responsible for the various surveys and bodies of data, including its own operations units. This may require more precise definitions or more complete classifications of data related to energy, improved samples in areas relevant to energy, special tabulations, or other adjustments, some of which DOE must be prepared to support financially. A number of specific recommendations to this end are made in this report.

4. Achieving the objectives of a comprehensive energy manpower information system requires more than just the development and integration of relevant data sources. It requires a focal point of dedicated interest, guidance and capability. DOE should therefore establish a staff whose principal and continuing function is to develop and utilize the comprehensive manpower information system. These responsibilities should include: keeping in touch with

all DOE needs for manpower information for operational and policy-formulation purposes; analyzing manpower data and reporting the results to appropriate officials of the agency; interpreting DOE data needs to other agencies that collect data and actively working to gain their cooperation in meeting these needs; developing and maintaining the comprehensive manpower information system; designing systems to tap DOE's internal reporting systems to yield data relevant to manpower, and securing the cooperation of the operational staff to achieve this; and through their own research or by research contracts or grants, advancing the art of manpower analysis as it applies to DOE's problems. This is a full-time job for several persons.

5. A central file of all publications relevant to energy manpower supply and demand and an index of relevant data sources should be established and maintained in the DOE organizational component primarily concerned with energy manpower. The Federal Energy Information Locator System (FEILS), now in the DOE, could be adapted to this purpose, in consultation with the manpower analysis staff. The library of data sources collected by Kramer Associates, Inc. in the course of this project will be turned over to the DOE as the nucleus of this file.

6. Although the benefits of computerization have sometimes been oversold, we believe there are advantages in using computers for organized storage and retrieval of selected energy manpower data, even in advance of establishing the kind of statistical convertibility and comparability that would permit analytical manipulation among the various data sources now in being. This issue involves questions of feasibility and costs versus benefits that go beyond the scope of this project. We recommend a review of these issues, looking toward a later more complete computerization, by a panel of disinterested manpower specialists with competence in computer systems.

7. Although the DOE is the central and responsible authority on issues relating to energy and energy manpower, other government agencies have an interest in these issues and are the sources of current data on R&D, education, employment, etc. and the potential vehicles for collecting new data useful to

DOE. Their cooperation is vital in any effective implementation of a comprehensive energy manpower information system. We recommend that an interagency committee on energy manpower information be given high priority under the sponsorship of the DOE Assistant Secretary having responsibility for energy manpower information, to develop the cooperative interagency arrangements necessary. The authority of the Office of Management and Budget should be enlisted to gain support for this activity and to recognize the unique responsibility of DOE in this area.

II. SPECIFIC RECOMMENDATIONS

Listed below are the principal specific recommendations of this report. Additional minor recommendations are made in the report itself. The principal recommendations are grouped under the headings of "PRINCIPAL DATA SYSTEMS" and "OTHER IMPROVEMENTS."

A general comment should be made about these recommendations: the Department of Energy's data needs were the principal consideration in making these recommendations, not the costs or operating constraints of the collecting agencies. An attempt was made to avoid obviously impossible or unreasonable recommendations, but the proposals were not discussed with the collecting agencies (since the authors of this report were not empowered to negotiate for DOE), and the DOE's information needs were given the benefit of any doubts. When the DOE asks collecting agencies to make these changes it may be found in some cases that they are difficult to carry out, or cannot be done without incurring large additional costs. DOE will be in the best position then to decide which recommendations have its highest priorities. Because so much of the manpower information system will use internal reporting systems within DOE or depend on modifying ongoing collection efforts of other agencies, it is not possible to estimate the costs of the recommendations.

8. <u>A Base Line Measure of Energy RD&D Manpower</u>

Manpower information now available for energy programs is piecemeal and contradictory. It was developed in response to specific operations problems or was adapted from data systems established for other purposes. It is not possible to secure from it a comprehensive total of the manpower supply engaged in energy activities. Most of our recommendations deal with piecemeal improvement of the existing series to make them more useful for energy manpower purposes. To give a more complete picture, it is recommended that a base line measure be established which will provide a comprehensive measure of scientific and technical personnel (STP) engaged in energy RD&D, by field of energy and selected occupations. Such a measure would encompass STP engaged in both private and publicly funded RD&D. The employment series covering the various sectors should be related to it. It can best be developed from the forthcoming 1980 Census of Population as a part of a post-censal survey program similar to that conducted in 1972 following the 1970 Census. Mechanics include identification of those employed in energy RD&D through the proposed up-date of the National Sample of Scientists and Engineers sponsored by NSF, and a follow-up survey to secure additional characteristics data important for energy manpower purposes. (See page IV-15.)

9. <u>Development of a Directory of Establishments Conducting Energy RD&D</u>

Energy RD&D activities are carried on in diverse industries by many companies. While many industries are unique with respect to their products and services, there are many industrial environments outside the so-called energy-intensive industries in which energy RD&D activities are performed. In order that the manpower information system may focus on the establishments in which energy RD&D is conducted, it is recommended that a Directory of such establishments be assembled. This Directory would be compiled from Federally-funded energy contractors, industrial directories, trade associations, survey respondents such as those responding to the Oak Ridge National Laboratory inventory, etc. It would serve both to measure the general extent of national involvement in the energy programs and their incidence in the various economic sectors, and also to provide a universe from which survey respondents can be selected for periodic and special manpower reporting. (See page IV-17.)

10. A System of Periodic Reporting on Energy RD&D

The DOE now has a multiplicity of reports submitted by its divisions and contractors in response to specialized operations requirements. Many of them contain some manpower information. However, these collections do not add to a comprehensive portrayal of manpower engaged in DOE funded programs. We recommend that DOE establish a more comprehensive reporting system which will permit annual estimates of scientific and technical personnel engaged, and expenditures involved, in energy RD&D.

This reporting system would consist of four segments based upon source of funding and organization: 1. DOE departmental and laboratory programs staffed by Federal Government personnel, and Government-Owned, Contractor-Operated facilities (GOCO's); 2. Other DOE-funded programs of contractors and grantees; 3. Other Federally-funded energy RD&D programs; 4. Energy RD&D programs that are not Federally funded.

It is further recommended that DOE administrative reporting, such as that established for the GOCO's or in the Uniform Contractor Reporting Guidelines, to the extent feasible, be the vehicle for achievement of the more comprehensive system. It is recognized that this may not always be practicable, as in the case of the non-DOE funded RD&D. In such cases, DOE might arrange for direct, contractor, or other Government agency collection. It is reasonable that DOE should need more detailed and complete information on its own and its contractor programs than on the other energy RD&D programs.

The DOE and GOCO establishments should report annually on energy RD&D employment and costs by type of energy, RD&D stage, and worker characteristics for selected STP occupations. Adaption of operations reports may be the feasible collection method for this purpose.

Other DOE-funded energy RD&D contractors and grantees would be called to report consistent but less detailed information on employment and expenditures. Again, operations reports might be adapted to provide such information, but other options may be more practicable.

Information on energy RD&D funded by other Federal agencies would be sought through cooperative arrangements with such agencies. Consistent employment and expenditures data for such RD&D projects might be collected directly by DOE or through a collecting agent, such as the National Science Foundation.

The final element of the system involves the coverage of establishments engaged in energy RD&D without Federal funding. This element completes the coverage of all segments with respect to STP engaged in energy RD&D, and, since it is of the least direct interest to DOE, would reasonably include the least detail. Information should be sought on STP occupations, type of energy involved, RD&D stage, and amount and sources of energy RD&D expenditures. Specifications for this collection, which would involve samples of industrial, university, and other establishments, should be developed in cooperation with the National Science Foundation which is now the principal collector of R&D data. If mutually acceptable arrangements can be made with NSF, it could well serve DOE as the collecting agent, as recommended previously, in lieu of direct collection. If not, DOE should undertake direct or contractor collection, utilizing the Directory of Establishments Conducting Energy RD&D recommended above. (See pages IV-18 to IV-21.)

11. A Reporting System on DOE Training Support

DOE's development of policies with respect to graduate student support, both direct and under research programs, would be aided greatly by the provision of more adequate information on the subject.

Therefore, DOE should take steps as soon as possible to establish a reporting system which will provide data on numbers, academic fields, man-years of training or employment, and other characteristics of all persons receiving support under such training programs as fellowships, traineeships, research assistants and post-doctorals. The system should cover all relevant institutions of higher education, related national and other laboratories, and similar organizations having DOE support under which students would be involved. (See page IV-76.)

OTHER IMPROVEMENTS

12. Need to Clarify Definitions of Energy RD&D

DOE should move to achieve a unified position both in the Department and with other agencies on the detailed elements within the taxonomies of energy activities to be used for collection of information included in the manpower information system. These taxonomies should be compatible with other reporting needs in the Department. A substantial amount of detail is required in the energy taxonomies to permit analysis of manpower issues. The Department also should, in concert with other data collection agencies (NSF, the Bureau of Labor Statistics, etc.) and with consideration of all departmental requirements, establish and clarify definitions for the several stages of RD&D activity, including basic and applied research, development (possibly with more than one stage), demonstration, and R&D plant.

Employment Data

13. Usefulness of the NSF-sponsored National Sample of Scientists and Engineers is seriously limited by sample inadequacies. We recommend that DOE work with NSF and Census to include technicians and to improve the sample with respect to STP manpower not in the most recent Census of Population. Type of energy should also be ascertained for those engaged in energy RD&D. (See page IV-3.)

14. The National Research Council biennial Survey of Doctoral Scientists and Engineers identifies doctorates engaged in "Energy or Fuel," but not by type of energy. DOE should encourage the inclusion of such information in the future and also the classification of private sector employment according to the Standard Industrial Classification. (See page IV-5.)

15. We recommend that the content of the DOE Survey of Nuclear Employment be encompassed by the proposed expanded DOE reporting system. (See page IV-6.)

16. DOE is now responsible for reporting by regulated energy industries formerly the responsibility of Federal Power Commission and the Interstate Commerce Commission. It is recommended that DOE review the manpower aspects of such reports with a view of standardizing the reporting specifications and publishing the occupational and related data. (See page IV-13.)

Labor Market and Mobility Data

Transfers between occupational fields and immigration and emigration movements significantly affect the supply of manpower available for energy RD&D, and information on the nature and extent of these movements are needed to assess labor market conditions. We therefore recommend that DOE should initiate action with other appropriate agencies to accomplish the following:

17. The Census Bureau should be urged to continue to collect data on occupations held 5 years earlier in each population census; to collect them on a sample larger than the 5 percent of the population sampled in 1970; to make the tabulations on the whole sample available for analysis; and to conduct research looking toward greater accuracy of occupational reporting and coding. (See page IV-46.)

18. The Immigration and Naturalization Service should be urged to improve its statistical operating data on immigration, with particular emphasis on

improved classification, tabulation and publication of occupational information on applicants for immigration, and to consolidate the original application data so that they may be accessed for special analytical needs as they develop, with due regard given to the confidentiality of these reports. More detailed instructions should be given in applications for immigration, and more detailed instructions should be supplied to consular officials, to improve the accuracy of occupational designations of applicants for immigration. Checklists and definitions should be supplied on critical occupations and on those subject to preferential admission. Periodic follow-up surveys should be made on the employment status of immigrants; a key objective should be to trace whether immigrants work in the occupations in which they listed themselves before immigration. (See page IV-52.)

19. The INS should also be urged to develop information on the emigration of U.S. scientists and engineers, in order to fill a significant gap in our knowledge of scientists and engineers supply. A program of international cooperation in the collection and exchange of data on immigrants, by country of origin, may be the ultimate answer to a difficult collection problem. (See page IV-53.)

20. To determine the effects on energy manpower supply of shifts between fields of training and of employment, DOE should work with NSF and the National Center for Education Statistics to assure that their surveys of the work experience of graduates collect and tabulate field of degree and field of work data to meet DOE's special needs. (See page IV-54, 55.)

21. <u>Manpower Intelligence Network</u>

DOE should establish a "manpower intelligence network", consisting of key individuals in intramural laboratories, GOCO's, and in some selected major DOE contractors, chosen because of their familiarity with labor market conditions. This network would serve as a "quick response" panel for supplying brief reports on current and possible future recruitment and training problems on scientific, technical and skilled manpower for energy RD&D programs. (See page IV-61.)

Earnings Data

Information on earnings is important for assessing and responding to labor market supply and demand conditions for energy RD&D manpower and has significant uses for RD&D program management. We therefore recommend:

22. DOE should formally review the administration and procedures of the Battelle National Survey of Compensation, or convene a panel to conduct such a review, with the aim of improving the survey's reliability, now prejudiced by low industry response rates. (See page IV-24.)

23. DOE should explore with the Bureau of Labor Statistics the enlargement of their PATC salary survey coverage to identify significant individual engineering fields, which are now grouped together, and to consider inclusion of one or more scientist occupations in addition to chemists. (See page IV-27.)

Education and Training Data

A considerable amount of information is available on the training of persons for employment in energy RD&D programs. However, certain improvements can be made to fill existing gaps and weaknesses, particularly for the less than professional level occupations. Specifically, DOE should initiate programs to make the following data available:

24. DOE should determine the types, levels and sources of training received by employed energy technicians through occasional surveys of such personnel, their supervisors and their employers. Then selected surveys of such sources of training could be undertaken, including information on content, facilities and type of instruction involved. (See page IV-77.)

25. DOE should conduct another survey of community and junior colleges, technical institutes, and similar institutions to provide data on the

number of energy-related courses, options and curricula being established in these schools. (See page IV-72.)

26. DOE should request that the National Center for Education Statistics reinstitute collections of data on enrollments in organized occupational curricula (including identification of energy-related options.) (See page IV-73.)

27. DOE should lend its support -- moral, financial, or other -- to the orderly and rapid conduct of the Higher Education General Information Surveys (HEGIS). Emphasis should be placed on making DOE data needs known to the National Center for Education Statistics -- particularly on fields of study relevant to energy. DOE also needs assurance of continued collections, especially those providing data on detailed field or program categories, e.g., upper division and graduate enrollment. (See page IV-63.)

28. For the annual compilation of information on Federal R&D by functional category (defense, space, energy, etc.), DOE should request NSF to provide further specifications, definitions, or explanations regarding the functional classifications. The present method used -- judgment and estimate by NSF staff -- is probably more reliable and consistent than direct delineation by the agencies. However, users of such data are unsure of the bases of decisions made on functional classifications. (See page IV-81.)

29. For the annual survey of R&D expenditures in the industrial sector, DOE should represent to NSF that the current exclusion of R&D in psychology and the social sciences, particularly the latter, omits certain R&D of relevance to energy programs. (See page IV-85.)

CHAPTER I

THE NEED FOR A COMPREHENSIVE ENERGY MANPOWER INFORMATION SYSTEM

A. INTRODUCTION

This study was designed to assist the Energy Research and Development Administration in its mission of encouraging, supporting and conducting research, development and demonstration (RD&D) programs aimed at improvement and expansion of energy resources and capabilities.

To carry out this mission, ERDA was directed by law to assess RD&D requirements and to help assure an adequate supply of manpower to meet these requirements. One of the means specified was to assure the collection, analysis and dissemination of necessary manpower data.

A great deal of data have been collected that bear directly or indirectly on one aspect or another of manpower engaged in energy RD&D. However, there has been little systematic effort to identify, evaluate and interrelate these data and to explain their usefulness -- and their limitations -- for systematically assessing the adequacy and availability of highly trained manpower to conduct RD&D programs. In a context in which complex and multiple research objectives are being pursued simultaneously on a scale which has been rapidly expanding, and where the achievement of individual objectives may take several years and require the employment of personnel with long years of specialized training, there is a clear need to identify the information that is required to assess manpower supply and demand for these programs, make the information available for use in such assessment, and describe how the information can be used. The current project constitutes the first step in such an effort -- the specification of a Comprehensive Energy Manpower Information System (CEMIS) for energy research, development and demonstration.

Late in the course of this project, it also became necessary to consider the broader needs for manpower information of the Department of Energy into which ERDA's functions are now incorporated. We believe there is a potential for the system proposed in this project to be adapted to those broader needs, and we recommend that DOE consider not only the use of the proposed system to assist policy formulation and management of energy RD&D, but that it also consider further elaboration and modification of the system for DOE manpower information needs.

In view of some current usages and a popular connotation in scientific circles, the term "information system" requires clarification. The information system treated in this project is not limited to a computerized setup relying on a statistically consistent data base that can be stored, manipulated for mathematical conclusions and retrieved electronically -- although such an ultimate process can be foreseen when a body of data is developed that is reasonably adequate in content and coverage and reasonably consistent for purposes of comparison.

Rather, the system specified in this project is a logical structure of integrated information components that can be related conceptually and empirically to the task of measurement and assessment of manpower supply and demand involved in the conduct of energy RD&D. This system will identify the appropriate data sources and establish the logical relationships among them; it will indicate the limitations of data coverage or interpretive validity and make recommendations for data improvement; and it will provide guidance to the interpretation of the data and point to the additional data that may be needed for confirmation. This report aims at drawing the design for the framework of the system and describing the procedures for constructing estimates of the supply/demand situation and producing other essential informational bases for guiding policy decisions that involve utilization of highly trained manpower in energy RD&D.

In specifying the data components of the system, we regarded the practical mandate of this study to focus on the information that exists, and only after identifying what is available and evaluating its utility in the logical structure, did we consider and propose the statistical improvements and innovations that we consider essential for the purposes of RD&D policy formulation and program management. While we believe there may be advantages in mechanizing the storage and retrieval of presently available data sources, computerization for the purpose of programmed data manipulation does not at this point appear to be feasible.

B. WHY ARE WE CONCERNED WITH MANPOWER FOR ENERGY RD&D?

The elements of our national energy situation which lead to a concern for RD&D manpower can be simply stated. Cheap and readily available energy has been a critical element in our way of life. But the supply of such energy now appears to be in jeopardy. The national demand for energy continues to increase while new supplies of oil and gas, which supply the bulk of our energy, have not kept pace. Moreover, we have become increasingly dependent on foreign supplies of oil, and these sources have proved to be expensive and undependable in a time of international tension. The increased costs of energy have in addition radically altered the international balance of payments and the domestic price structure upon which many important industrial and social decisions were based.

While some of the required responses to these elements of the energy situation lie in the field of public policy (for example, measures involving conservation and pricing), a large role in the resolution of energy problems has also been assigned to research and development. Virtually all expressions of national goals now include those of devoting scientific and technical resources to development of additional and alternative supplies of energy of greater dependability and lower cost. They also aim at conservation of energy supplies by developing techniques for eliminating wasteful uses and for increasing efficiencies in use.

The need for large scale and systematic deployment of research and development resources to the solution of energy problems -- and the need for data about manpower resources to conduct these activities -- is revealed by increasingly accurate and relevant information about the nature of the energy crisis. The collection and analysis of information that identifies and describes the problems is in itself a function of research that bears on the subsequent decisions regarding the directions of further RD&D efforts. This fact-finding function is required so that administrators and the public can determine what the problems are, how significant they are, and find guidance in selecting the options that are available. The fact-finding function should also supply manpower information, showing the resources available to pursue these options.

1. A Successful RD&D Response to the Energy Problem Requires the Availability of Highly Specialized Manpower

The compulsions imposed by the nature of the energy crisis make it likely that important shifts will take place in energy production, conversion, transmission and use. To reduce reliance on foreign supplies, to increase conservation and efficiency of energy use and to develop new sources of energy requires scientific exploration to develop new knowledge and technology. Highly specialized scientists, engineers, technicians and craftsmen will be needed for virtually all of the approaches to the energy problem: to explore and develop unconventional sources of energy -- for example, the sun, winds, and ocean; to devise new approaches to the conventional sources -- fluid coal combustion and magnetohydrodynamics; and to improve conservation and efficiency in use -- lower-loss electrical transmission systems, more economical auto turbine engines and alternative methods of propulsion and transportation. Highly trained manpower will also be needed to determine the economic feasibility of the remedies proposed, to gauge their impact on our way of life and to assess the risks they pose to individual health and safety and the environment.

The record of the past suggests that this country can meet the current energy crisis successfully if the national sense of purpose is to do so. If the commitment is serious and sustained, and adequate resources are devoted to the effort, the country can make the scientific advances and develop and apply the needed technologies. Depending on a number of factors, a considerable variation is however possible in the degree of success achieved and even in the nature of the outcomes. If the skilled manpower required is not available in sufficient number or with appropriate qualification, potentially significant improvements in energy resources or capability can be delayed or their effectiveness largely frustrated. Even if the energy improvement objectives are met under these conditions, other undesirable effects can occur. If, for example, the education and training of a future supply of specifically specialized manpower is ignored where the manpower demands of RD&D programs imply large additional long-term needs, then efforts to induce current employment shifts can lead to program delays and distortions in the general wage structure. The absence of accurate information on manpower supply and demand can also lead to a wasteful deployment of skills and a reduced general efficiency in the employment of skilled manpower.

On the other hand, many undesirable consequences can be averted if the skilled manpower requirements of alternative courses of R&D action are known, and if actions are taken consciously to minimize adverse effects indicated in the information on manpower supply and demand connected with each course of action.

2. The Growing Scale of Energy RD&D

Between 1973 and 1978, Federal support of energy R&D rose more than six fold to $2.8 billion.* The industry-supported energy R&D effort probably was half-again as large (roughly based on the previous ratio of industry to Federal energy R&D expenditures). Furthermore, there is also the demonstration effort -- the process of securing the adoption of technological and scientific innovations to commercial use -- the size of which is not known, although some part of it is included in the R&D totals, and some part is probably additional to those totals. Moreover, the content of the RD&D activities have ranged from studies of the impact of oil shale mining on water supplies to biomedical identification of energy-related hazardous agents, to cite only two RD&D programs abstracted at random. As the impact of the present energy situation continues to bear on the public, the demand for solutions and further increases in RD&D support will grow. It also seems likely that greater accountability for the efficiency of RD&D efforts will be demanded. Before decisions are made on RD&D programs, RD&D administrators will need to know and have to ask the questions that relate to the availability of requisite R&D personnel.

A program of research, development and demonstration requires one key resource that is not readily expansible: scientific, technical and skilled craft workers. The long lead time required to educate and train these workers makes it difficult to increase their number rapidly in response to the chang-

* National Science Foundation, Science Resources Studies-Highlights, NSF 77-320, Washington, Sept. 30, 1977, p.3.

ing imperatives of science and technology programs. Moreover, for research at the forefront of knowledge, only the most highly qualified or most specialized scientists can be productive; and it may take many months of additional training to bring an otherwise generally qualified scientist to that level. Other sectors of the economy are absorbing an increasing number of scientists and engineers, so that they are not easily available for energy RD&D; employment in these occupations, after growing rapidly in the 1950's and 1960's and then holding stable early in the 1970's, has resumed its growth. A decline in the college-age population is going to occur in the early 1980's as a result of a drop in births nearly two decades earlier. Experience shows that demand for some scientific and technical occupations increases faster than the average, while demand for others grows more slowly; it is possible, therefore that some occupations needed in energy RD&D may be among those in demand for other types of work. Thus the DOE has to consider the possibility that a resource essential to its work may be in short supply.

In sum, the energy RD&D effort is large and increasing and immensely varied. The decisions that will be made regarding its future content, scale and direction cannot prudently ignore consideration of manpower needs and resources.

C. SOME QUESTIONS THAT A COMPREHENSIVE ENERGY MANPOWER INFORMATION SYSTEM MIGHT ANSWER

1. Questions Directly Relating to Supply-Demand Adequacy

a. What is the Volume of STP Manpower Now Engaged in Energy R&D?

How is manpower deployed between energy technologies?...Stages of RD&D?...Occupations?...Industries? To what extent is manpower drawn from other sectors? What are the patterns of inter-sector flow?

b. Are Any of the Energy RD&D Programs Now Being Hampered by Personnel or Manpower Problems?

What is the nature and dimensions of these problems? What indicators reveal them? High quit rates? Inability to attract qualified workers? Employee dissatisfaction and low morale?

What are the possible causes: general shortages in the occupation, low ~~salaries~~ in the desired program compared to alternative employment; undesirable location, work situation, or working conditions; others? (The statistical indicators that identify the problems and causes -- or flag an alert to examine other relevant indicators -- would be tagged in this system).

What are the short-term and long-term options available for dealing with the problems: salary adjustment; improved working conditions or work relationships; recruiting and training workers in related occupations or specialties; others?

c. What Problems Should be Anticipated if a Series of Additional Large-Scale RD&D Projects are Undertaken in a Variety of Fields -- For Example, Solar Residential Heating and Cooling, Geothermal Electric Conversion, Coal Gasification?

-- What will be the impact of their aggregate staffing requirements on the available manpower supply in the occupational specialties required?

...At the inception of the programs?...In their later stages of development?

-- What competing requirements are there for these kinds of manpower? Currently? Prospectively? In what other sectors of the economy?

-- What are the recent employment trends in these occupations? Recent entries? Prospective entrants now in training?

-- Are there potentially qualified personnel in allied occupations or industries? Is there an empirical pattern of employment shifts into the required occupations that points to the areas of potential supply or suggests the magnitude or nature of employment substitution according to educational or experience qualifications?

-- What are the relative pay scales which accompanied previous shifts? What are these relative pay scales now?

-- What are the education and training requirements for the needed personnel? What lead time is required for training? (Years of training, age at earning doctoral degree).

d. As Energy RD&D Programs Expand, Will They Experience Manpower Shortages?

...In what occupations, when, in what localities?

This requires information on the kinds of questions exemplified in the following situation:

-- How many potentially qualified personnel are in the training pipeline? What are the enrollments and degrees-granted trends? What is the usual attrition rate between training for the field and actual employment? What are the fields into which these have shifted? What are the crossflows from other fields of training?

-- What is the status of incentive programs for entry into training for the desired fields (student and post-graduate support and basic research grants) in comparison with other fields? Is there a need for DOE policy initiatives aimed at influencing the supply of trainees or the content of training?

2. <u>Questions Indirectly Relating to Supply and Demand; Directly Relating to Management or Policy Needs Regarding RD&D Personnel</u>

a. Equal Employment Policies

-- Failure to carry out Equal Employment policies can hamper full utilization of manpower and can be a barrier to improved manpower supply.

-- Are Equal Employment Opportunity policies being carried out within DOE, in Government-Owned, Company-Operated plants (significant in energy RD&D and nuclear power development and production) and in private sector energy RD&D facilities receiving Government contracts?

-- Is there a pattern of de facto discrimination in employment that limits full utilization of manpower? Are women, blacks and other minorities receiving training for but not being employed in RD&D work?

-- Are there differences in pay between men and women for essentially equal work that imply possibly undesirable personnel policies?

b. Support Programs

-- Is the relative level of student support programs, fellowships and basic research support grants in energy affecting recruitment of potential energy R&D personnel vis-a-vis other fields?

The above questions and components of information required to answer them are illustrative and not exhaustive. Because all of the questions that may need asking and all of the information needed to answer them will not be foreseen, one specification for a manpower information system should be that it be flexible -- that it possess the capability for inserting and retrieving new components of information to meet changing focuses of management and policy concerns regarding the development and utilization of energy manpower resources.

The information system cannot, and should not, be used to answer questions about appropriate policy or technological feasibility, but it is the next level of recourse once the other decisions have been made.

The data sources required to answer the kinds of questions illustrated above necessarily cover more than those on energy RD&D manpower activities alone. Because a degree of fluidity exists between labor markets, developments occurring in certain non-energy sectors, or in certain non-RD&D activities, may have an impact on the supply/demand situation in energy RD&D activities. A discussion of these relationships and of the breadth of data coverage needed to reflect them is included in succeeding chapters.

The uses and users of an energy manpower information system also extend beyond that of the energy RD&D sector. In addition to policy makers and managers responsible for Federal energy RD&D programs, there are also university administrators, students and other potential RD&D practitioners, and officials concerned with educational policy who must often make decisions that require the information and analytical estimates that can be provided by a comprehensive energy manpower information system. The system described in this report envisages the ultimate availability of its information for a variety of uses of public benefit that will also aid in the efficient utilization of manpower for energy RD&D purposes.

D. THE PLAN OF THE WORK

In the following chapters, the framework and specifications of the system are laid out. The report is organized as follows: The scope of an energy RD&D manpower information system and the definition of its components are discussed in Chapter II. Chapter III delineates the logic of a system -- the conceptual and theoretical considerations that lead to the selection of the kinds of data and analyses that are significant for manpower assessment. Existing data sources are reviewed and evaluated in Chapter IV, which then goes on to specify the elements composing a comprehensive data system and describes how to develop them either by modifying existing sources or by creating new ones. Chapter V describes how these elements can be applied and utilized in manpower assessment. A preliminary appraisal of the manpower situation, based on presently available data, is given in Chapter VI.

The appendices include:

a) taxonomies for the classification of data;
b) detailed descriptions of the major data sources;
c) a bibliography of publications assembled and used in this project; and
d) a listing of the principal individuals interviewed in the course of the project.

CHAPTER II

SCOPE AND DEFINITIONS OF COMPONENTS OF THE MANPOWER INFORMATION SYSTEM

A. INTRODUCTION AND GENERAL

As important as energy activities have become, still the manpower engaged in RD&D (with respect to production, conversion, conservation, and improved utilization of energy) is relatively a small segment of the national labor force. When the focus of interest is narrowed further to the scientific and technical, the target population becomes quite small in size although not in importance. Taking private industry alone, of 1,180,000 scientists and engineers employed in 1975, 186,000 were in energy-related activities, and only 37,000 of the latter were in energy R&D, according to the National Science Foundation.* To this should be added those in energy RD&D in government, universities and nonprofit research organizations, in which they probably are even smaller proportions of total employment. A broader concept of energy RD&D would add to this number, but the point is that such manpower is still a small proportion of all scientific and technical personnel. An equally small portion of all doctorates are in energy RD&D activities -- about five percent.

However, this relatively small number of highly-trained individuals is engaged in a wide array of complex activities that are critical to our nation. We cannot take for granted that specialists will be available when needed. The nature and scale of the challenges confronted by energy RD&D are subject to change from a variety of circumstances. Therefore, for the Department of Energy's (DOE) purposes, it is important to (1) get complete information on the manpower employed on energy RD&D and (2) analyze the manpower situation

*National Science Foundation, Private Industry Employment of Scientists and Engineers in 1975 Shows 5-Year Decline, NSF 77-312, Washington, D.C. May 1977.

for them in the context of the total demand and supply for all members of each energy-related specialty in the nation, including those in activities other than energy and in work other than R&D.

Nor is this target population concentrated in a few industries or activities. It may be found in many locations ranging from routine design to exotic basic research. Developing a manpower information system does not easily fit the established patterns of reporting according to classifications of industries or occupations. The concept of energy RD&D as an important manpower activity cuts across traditional practice.

The main purpose of this section of the report is to describe generally the scope and limits of the Comprehensive Energy Manpower Information System and provide the more important or obvious measures, definitions, and taxonomies required. These include such areas as: energy research, development, and demonstration; energy activities; categories of manpower; occupational groups and specialties; fields of degrees and enrollment in higher education; and the physical and industrial location of energy RD&D programs.

These are some of the issues:

1. <u>How Is RD&D Distinguished From Other Activities?</u>

Which of the many activities concerned with energy under the DOE's scope of responsibility should be considered RD&D for purposes of the manpower information system, and how can they be distinguished from exploration, production, distribution, regulation, etc.? Also, what are the boundaries between research and development, between development and demonstration, seeing these activities as a continuum? Demonstration, the last stage before full commercial development, presents particularly difficult definitional problems.

2. <u>What is Energy RD&D?</u>

The actual core idea is clear, but the boundaries are hard to draw. Is there a subject-matter boundary to energy RD&D? If problems of corrosion arise in developing geothermal energy, or the strength of materials for boilers, or the electrical conductivity of metals, or the working properties of silicone as they apply to manufacturing solar energy collectors, or the environmental effects of strip mining - are these varied topics, with applications in non-energy fields, properly included in "energy RD&D"? (Perhaps the practical answer is that energy RD&D is whatever DOE is funding because it has been administratively determined to be relevant to DOE's mission.)

3. <u>What Kinds of Manpower Are Relevant?</u>

Workers on energy projects include scientists, engineers, technicians, skilled craftsmen (both in laboratory work and in building demonstration facilities), clerical workers, service workers (janitorial, protective, etc.), and others. Many of these workers require little training and are usually easy to recruit, but those with long learning periods, either years of college education or apprenticeship, cannot be recruited so readily if the supply is short. These are of the greatest concern from the point of view of manpower supply and demand. Which specialties are required for energy RD&D, especially by the new energy technologies being investigated?

4. <u>What Sectors Of The Economy Are Involved?</u>

Can energy industries or energy-related industries be identified? If so, the problems of getting data now collected or of collecting and analyzing new data would be made easier.

5. <u>How Can Graduates Who Constitute the New Labor Supply For Energy RD&D Occupations Be Identified?</u>

6. <u>How Should Information On Energy RD&D Manpower Be Organized To Be Most Useful To DOE?</u>

Among the possibilities are:

(a) Energy source (coal, oil, hydro-power, solar, etc.)

(b) Energy stage (exploration, recovery, conversion)

(c) Energy technology (utilization of waste heat, enhanced recovery methods, etc.)

(d) Location of program (DOE intramural, outside contract or grant, etc.)

7. <u>How Does An Energy RD&D Manpower Information System Relate To The Broader Economic and Manpower Context?</u>

How should the rest of the economy, and the rest of manpower (with which energy RD&D manpower is to some extent interchangeable) be taken into account in the manpower information system?

The general focus of the proposed manpower information system is the supply/demand balances of personnel (and the factors which affect them) necessary to carry out the nation's prescribed energy RD&D programs. Some of the relevant factors will require current, frequent measurement; others, more general and occasional analyses. The various factors affecting current and future supply and demand balances will be spelled out in later sections of this report. Some information needs are obvious -- the number of chemists currently employed in energy RD&D activities, or the planned expenditures for basic research in physics. In other cases, there is a need to quantify the effect of certain factors on future supply such as the relative participation of women and minorities in training programs.

Finally, the manpower information system needs to be delineated not only as to the specifics of energy RD&D, but also in the national context. It must be designed for maximum flexibility and possible expansion. Basically, the system should be designed to provide answers and measurement not only for current situations, but primarily to provide a basis for informed decisions and action on future activities.

The field of energy RD&D is undergoing rapid change as new technologies are explored and new areas of research opened up. Therefore, it is likely that economic sectors that had not been traditionally considered energy-related will become so, and that specialties of science and engineering that have not been involved in energy research will become involved, or that new specialties will emerge, including some on the boundaries between scientific disciplines. Such new occupations are the ones most likely to develop shortages that could impede the energy RD&D effort.

Further, the Department of Energy itself has just been formed of an amalgamation of several types of energy activities. The organizational issues will bring changes in content, goals, and other aspects of energy RD&D.

It is essential, therefore, that DOE be alert to the development of new occupations or specialties, as well as to the involvement of additional or new industrial segments involved in energy RD&D work, and to make sure that ongoing and planned data collection programs on manpower and RD&D activity include them.

In a comprehensive information system involving multiple data sources, we need to be concerned not only with accuracy and relevance in identification of components, but also with comparability of classifications among different data sources. For example, valid conclusions about differences in salary for different occupations, or for the same occupations in different establishments or industries, depend on accurate identification of the job and its work content, and of the components customarily affecting salary, such as training, experience, supervisory responsibility, and so on. To cite another example, valid conclusions about trends in employment in given specialties depend on uniform or consistent identification over time of the jobs reported on, particularly if different statistical series have to be relied on. The comment of Professor Leontief is pertinent in this respect. "An unreasonably high proportion of material and intellectual resources devoted to statistical work is now spent not on the collection of primary information but on a frustrating and wasteful struggle with incongruous definitions and irreconcilable classifications."*

There are in fact several classification systems, each claiming unique merit, that apply to the relevant data describing manpower supply and demand. It is the reality of these different systems that prompts the need for practical decisions about the taxonomy of data sources in a comprehensive energy manpower information system -- what taxonomy should be used in the development of new data sources? -- what taxonomy is the most meaningful for the uses of energy manpower information and should become the common standard for analytical presentation when data sources with different taxonomies must be used?

The interests of economy and pragmatism dictate that use should be made of the systems that exist, and that techniques of analytical convertibility among different systems should be relied on for comparative use wherever such convertibility can be achieved and the results can be applied practically to the manipulation and analysis of data. These principles would limit modifications or innovations in taxonomy only to those cases where the existing taxonomies prevent or seriously hinder meaningful use of critical elements of data. The considerations applicable to the specific areas of data are discussed below with recommendations on the taxonomies most relevant and useful for an energy manpower information system. Fortunately, there are far more elements that are equivalent than different among the various taxonomies, particularly those components relating to scientific and engineering manpower. The differences that exist have become increasingly less important a barrier to use as convertibility patterns have been established. Far more frustrating to users has been the absence of meaningful or timely data or detail on categories of information needed.

* Wassily W. Leontief, "Theoretical Assumptions and Nonobserved Facts", American Economic Review, March 1971, p. 6.

B. ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION

Energy RD&D can be broadly defined as that research, development, and demonstration activity whose purpose is to increase energy resources or capabilities, (including both basic and support research related to these ends). One dimension along which information on energy RD&D manpower or expenditures has to be classified is the progression in the development of scientific and technological activity from basic research towards full commercial use of a technology -- the distinctions among basic research, applied research, development, demonstration, and other stages leading to full commercial utilization. These distinctions are significant for manpower in part because the total manpower per dollar spent and its occupational composition at each of the stages or phases along this progression may differ substantially. Furthermore, it is possible that additional stages or phases in scientific and technical activity may be established as the programs of the new Department of Energy develop.

General and specific measurements of research and development have been carried out for more than two decades by the National Science Foundation (NSF) and have been generally accepted by policy makers and analysts. A number of other agencies and organizations have collected information on spending for research and development, but these are either tied to NSF definitions and practices or are minor data collections. Also, the Office of Management and Budget largely has concurred in the NSF definitions and categories. Therefore, it is recommended that the NSF conceptions of the R&D process be utilized within the Comprehensive Energy Manpower Information System.

The definitions used by the National Science Foundation (NSF), both in measuring Governmental obligations and authorizations as well as operational programs in industry, universities, intramural Federal laboratories, and by other performers follow below.

A special comment should be made about activities now generally termed demonstrations. In the past such activities may have been carried out traditionally either as a part of the R&D process or range of functions or have been considered more as a part of the production process. In any case, demonstrations have achieved more prominence both in terms of delineation for budgeting within the Federal R&D programs as well as in private industrial settings. One primary reason for this is the onset of large-scale programs such as in space and energy which are beyond the risk and other capabilities of single firms or organizations. The NSF presently provides no specific definitions for demonstration activities for its various surveys. For Federal obligations, the agency staff is able to exclude or include activities on the basis of program definition. However, in the case of extramural performers of R&D, it is not clear as to the inclusion or exclusion of demonstration programs.

The main purpose of such activities is to provide information, knowledge, and data (technical and economic) as to commercial feasibility. However, the pure dissemination of information gained from research, development or demonstration would not be included. An ERDA official testifying before a Congressional Committee indicated:

> "Some energy technologies appear to be technically feasible and are at the point where they could be demonstrated: tertiary oil recovery, solar hot water heating, solar space heating, biomass conversion, synthetic gas from coal, synthetic liquid from coal and/or shale, and geothermal power. Many of these technologies are not being commercialized because the technology is simply too expensive, resulting in the price of energy produced from projects using these technologies to be greater than competing prices from traditional energy sources, like foreign oil. Others, like certain solar technologies, appear to be cost effective on a life cycle basis but are not being widely commercialized because of higher initial costs and, perhaps, because of lack of information on the part of the consumer."*

* Review of GAO Report on Commercialization of Emerging Energy Technologies, Hearing before Committee on Science & Technology 94th Congress, 2nd Session #99, August 30, 1976.

It is obvious that a definition of demonstration programs will have to be established so as to clearly delineate them for inclusion or exclusion in R&D.

The definition for demonstration activities given below is based on selected program definitions within the Energy Research and Development Administration (ERDA) and those developed in a study of the role of RD&D in energy made by the University of Oklahoma.* All of the stages are shown as being subsumed under research and development.

Research and development consists of basic and applied research in the sciences and engineering and activities in development, all defined below. In terms of fields, the natural sciences--life, (including medical sciences), physical -- and engineering, as well as the social and psychological sciences are covered.

Research, which encompasses both basic and applied, is systematic, intensive study directed toward fuller scientific knowledge of the subject studied.

Basic research for three of the sectors -- Federal Government, universities and colleges, and other non-profit institutions -- follows the NSF definition of basic research which stresses that it is directed toward increases of knowledge in science with "... a fuller knowledge or understanding of the subject under study, rather than a practical application thereof". To take account of an individual industrial company's commercial goals, the definition for the industry sector is modified to indicate that basic research projects represent "...original investigations for the advancement of scientific knowledge... which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company".

Applied research follows generally the core definition in the NSF questionnaire sent to the universities and colleges: "Applied research is directed toward practical application of knowledge". Here again, the definition for the industry survey takes account of the characteristics of industrial organizations it covers "...research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes". By this definition, applied research in industry differs from basic research chiefly in terms of objectives of the reporting company.

*Science and Public Policy Program, University of Oklahoma, Our Energy Future, The Role of Research Development, and Demonstration in Reaching a National Consensus on Energy Supply, Norman, Oklahoma 1976.

Development for the NSF surveys may be summarized as "... the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes".

Demonstration or demonstrations may be generally defined as those activities ranging between pilot plants and large-scale commercial production. They have the purpose of providing both hardware and software information with sufficient reliability and credibility to lead to commercial decisions. Commercial-scale demonstrations represent the final stage in a scaling-up process which begins in the laboratory and progresses through various development phases. Demonstrations normally take place cnly after a technology is thought to be well understood and is at or near commercial viability. Another definition of demonstration activities proposed for a survey was: Verification of economic and environmental viability for commercial application, through design, construction, test, and evaluation, of large scale energy systems in operational circumstances.

The definition of current operating costs for R&D used in the NSF surveys is as follows: "Funds used for research and development refer to current operating costs, consisting of both direct and indirect costs including depreciation, insofar as this information is available to respondents. Capital expenditures are excluded by definition and this practice is followed in the surveys of the industry, universities and colleges, and other nonprofit sectors. Under the accounting practices of some Federal agencies -- particularly the Department of Defense -- data on Federal R&D funds, which are available in detail only in terms of obligations rather than expenditures, do not include an allowance for depreciation, but do include some obligations for capital items."*

Finally, it is necessary to provide for the inclusion of that research, development, and demonstration which is energy-related. This is considered in Section C. Energy Activities.

*National Science Foundation, National Patterns of R&D Resources Funds and Manpower in The United States, 1953-1977, NSF 77-310. Washington, D.C. 1977, p. 19.

1. Research and Development in Broad Sectors of the Economy

The National Science Foundation (NSF) follows a four-sector division in surveying R&D funds and personnel and maintaining time series for expenditures and employment. This division is based on an approach that attempts to take account of both the legal nature and major functions of organizations active in financing and performing basic research, applied research, and development. Grouping diverse types of organizations into discrete sectors, however, requires certain arbitrary judgments because of the mixed nature of many organizations, particularly those in the university and other nonprofit sectors. Government-Owned, Contractor-Operated facilities (GOCO's) for R&D, termed Federally-funded R&D Centers (FFRDC's) by NSF, are generally included in the sector of the organization holding such contracts. Surveys of energy RD&D (manpower or dollars) need not be done along these sectoral lines because of the nature of energy programs. However NSF surveys provide the basic data on all R&D activity and it will be necessary to link the basic data to the information DOE does obtain.

The government sector is made up of the several types of government. Surveys are conducted annually of agencies of the Federal government and occasionally (2 - 3 years) of State government agencies. Local government agencies have not been adequately surveyed.

The industry sector consists of both manufacturing and nonmanufacturing firms and their establishments. These companies and establishments including organizations such as those in selected service industries, may be classified in major industry groupings. Federally Funded Research and Development Centers (FFRDC's) administered by industrial firms are also included.

The universities and colleges sector is composed of all institutions of higher education, both public and private. The term "universities and colleges" is used to refer to the academic institutions as a group without the associated FFRDC's administered by the schools for various Federal agencies. The universities and colleges include colleges of liberal arts; schools of arts and sciences; professional schools, such as engineering and medical schools, including affiliated hospitals; associated research institutions, and similar organizations, which are integral parts of the universities and colleges; agricultural experiment stations, and associated schools of agriculture, and community or junior colleges.

Funds used at the universities and attributed to the universities sector as a source consist of several components: (1) State and local government funds separately budgeted for research and development, and (2) unrestricted or general funds which the institutions themselves have been free to allocate for research. Funds from the Federal Government, industry, or other nonprofit institutions, which are supplied in the form of grants or contracts for research or development at a university, are credited to the appropriate source in the performance of research and development by universities and colleges. Thus, research contracts from industry are treated as university performance funded by industry as the source, whereas funds given to the institution by industry for general educational purposes and used by the school, at its discretion, for research, are treated as university performance financed with the university's own funds.

Institutions in the other nonprofit Sector fall into two general groups: (1) organizations whose activities are primarily "granting" in nature, namely private philanthropic foundations and voluntary health agencies, and (2) public and private organizations that are involved in performing research and development, comprising separately incorporated nonprofit research institutes, professional societies, academies of science, museums, zoological gardens, botanical gardens, arboretums, nonprofit hospitals, and FFRDC's administered by nonprofit organizations, (such as Battelle Memorial Institute).

Both the university and the other nonprofit sectors contain private and public institutions -- the latter are closely associated with State or local governments. A number of organizations in both sectors, as well as in industry, also receive State and local government funds.

2. Research and Development by Fields of Science

The fields of science used in the NSF surveys are divided into eight broad field categories, most of them consisting of a number of detailed fields. The broad fields are life sciences, psychology, physical sciences, environmental sciences, mathematics, engineering, social sciences, and other sciences not elsewhere classified. The NSF has collected and categorized data on research and development by field of science for several reasons -- primarily because of its responsibilities and interest in basic and applied research as national goals per se. Because of the interdisciplinary nature of development, such expenditures have not been classified by field of science. Since a substantial part of energy RD&D programs is either development or demonstration, it is not recommended that information on energy RD&D, manpower or dollars, be collected and classified by fields of science. Energy RD&D manpower data will of course be gathered in terms of occupations.

C. ENERGY ACTIVITIES

The primary focus of the development of the Comprehensive Energy Manpower Information System (CEMIS) under the present project was on manpower in energy research, development, and demonstration. Therefore, the priority for delineating data elements and components for the system should be for those specifically related to energy RD&D. However, for several reasons the development of the system cannot now on one hand be restricted to energy RD&D nor extended on the other hand to include all relevant activities. It is extremely difficult at this time to draw boundary lines around energy RD&D or its component stages. One problem lies with the definition or delineation of demonstration programs in the progression between development and commercialization. Second, the programs being carried out by the Energy Research and Development Administration (ERDA) were not restricted to research and development (e.g. U-235 production) nor to energy matters (e.g. weapons development). Now with the amalgamation of various component agencies, including ERDA, into the Department of Energy (DOE), it will be even more difficult to restrict relevant categories in a final version of the system to energy RD&D. It appears from the charter given to DOE that its interests go beyond those activities.

At this time and with available resources the system will be prescribed primarily in terms of the more limited area of energy RD&D at least for activities extramural to DOE. Further delineation of the system to all energy activities will await developments within the new Department of Energy. For intramural programs of the DOE and Government-Owned, Contractor-Operated establishments (GOCO's) the system should be extended beyond energy RD&D.

In general then, the Comprehensive Energy Manpower Information System must be capable of producing information for energy-related activities both in RD&D and other areas, as well as being expansible to total or national activities. In this first sense then, all energy activities should be set forth in detail or by a number of boundaries in order that all potential information needs be examined. In the broadest sense RD&D should be conceived of as being related to all other energy activities, that is: RD&D is possible in almost every energy-related function.

There are several broad approaches to the delineation of energy activities, not all of which need to be utilized as methods of classifying energy RD&D manpower. These include:

> <u>Energy sources</u>, such as coal, gas, nuclear, water, geothermal or solar.
>
> <u>Energy stages</u>, such as exploration; conversion, transmission, and utilization.
>
> <u>Energy technologies</u>, such as enhanced recovery of oil, electric conversion efficiency, improved industrial conservation, or various methods of coal gasification.

Certain other energy activities either fall astride the above three categories or apply to nearly every energy activity. In addition to RD&D these include basic science support; environmental impacts; health, medicine, and safety; and efficiency of utilization or conservation. Also, energy activities can be delineated in terms of location or geography i.e., foreign and domestic; on-shore and off-shore; above and underground; Eastern, Western or Alaskan, and even by State and locality. The several sets of categories would be useful to some extent as delineators in the analysis, planning, management or actual operation of energy RD&D programs and thus have relevance to manpower.

Another set of descriptors could be made particularly for energy RD&D programs. One expression of these categories is in terms of problems to be solved, or information required, characterized sometimes as technical support areas. As RD&D programs prove successful, next steps or progressions -- not now planned -- can be undertaken. This set of descriptors is closely akin to that for energy technologies; however, in many cases the categories are only described as technical support to any given technology. In any case there is no established taxonomy -- only what amounts to programmatic problem areas -- and none is suggested.

Further definition and description of the major sets of energy activities may now be set forth:

1. Energy Sources: Includes fossil fuels (including coal, natural gas, crude oil, shale oil, tar sands), nuclear fission, nuclear fusion, geothermal, solar (heating and photovoltaic), wind, biomass (combustible and conversion to fuels), and water (thermal and motive).

This set of categories is obviously useful in measuring manpower utilized in developing and producing alternate energy sources. Will RD&D on solar energy need more scientists and engineers than geothermal and in what numbers and what occupations?

2. Energy Stages: Includes activities ranging from exploration through extraction, conversion, distribution, etc. As indicated previously, there can be conservation; research, development, and demonstration; environmental concerns, and basic science support applicable to any of these stages. This set of energy categories is useful primarily in determining what particular energy source will create needs for personnel and for what types and what stage and time will such personnel be needed. (See Appendix A for the listing of energy stages.)

3. Energy Technologies: These categories are almost without limit since they constitute the sum of problems requiring solution, supply and utilization issues, RD&D progression or the process of applying specific knowledge to energy goals. These technologies range through all energy stages from enhanced coal, oil, and gas extraction; coal gasification (high, medium, and low BTU); methanol; fuel oil; solvent refining; LWR, HTGR, FBR fuel fabrication, and spent fuel processing; fuel cells; magnetic and laser performance standards; coal slurry pipelines, crude oil pipelines (thermal protection, continuous flow problems), in-situ coal gasification; power plant waste heat use systems; super-conducting power transmission, flywheel storage; ocean thermal gradients; hydrogen energy transmission; etc.

It would appear that energy RD&D manpower should be sought and classified in terms of these technologies in order to measure the impact which the development and adoption of specific technologies would have. However, it is also recognized that there are in practice similar needs for measurement of manpower in terms of sources and energy stages. Appendix A includes the DOE budget and reporting classifications which indicate most of these technologies.

4. Present Energy Classification of the Department of Energy (DOE): At this time, it is not possible to state what types and how many energy data classifications will be adopted by DOE. The agency is now being formed of several preceding organizations nearly all of which had various taxonomies established for dealing with their several data issues and problems. Whatever taxonomies or structures are adopted, it is important that the needs of the manpower assessment system be met as much as possible. Similarly, it is vital that the classifications embodied in the manpower information system be compatible with those established for other DOE uses. For an "internal" manpower and related (RD&D expenditures) system to cover all intramural activities plus those conducted in national laboratories and other government-owned, contractor-operated facilities, and those conducted under direct DOE contract and grant support, it would appear that a standardized "program based" taxonomy would be indicated. On the other hand, manpower information obtained on non-DOE supported energy RD&D should be classified into energy categories compatible with but not necessarily the same as the program-based system, nor in as fine detail.

At the time of the organization of the Department of Energy there was no single, standardized and established system for classifying energy activities. However, one dominant system now accounts for all funds provided to and used by DOE. This is the "budget and reporting classifications" taxonomy set up by the Comptroller's Office at the time of the Departmental organization.* This taxonomy consists largely of ERDA categories which had been developed over a period of many years starting in the days of the Atomic Energy Commission, supplemented by categories used by FEA, FPC, and other agencies joining DOE. A truncated version of the budget and reporting system is included in Appendix A.

This "budget" system can be described generally as one covering all of the types mentioned above -- sources, stages, and technologies -- plus several other bases. For example, there are categories covering the several sources (coal, solar, fission, etc.), the several technologies (heating and cooling demonstration, coal gasification, the several stages (solvent extraction, advanced research and supporting technology), and categories covering the non-energy activities of ERDA (space applications, high energy physics, U-235 production, development on current weapons requirements), as well as on reimbursable operations, and expenditures for capital equipment and construction.

*Department of Energy, Interim Management Directive, IMD 1105, September 29, 1977.

Similarly, the ERDA had classifications of its activities embodied in the budget cycle -- line items presented to and acted on by Congress -- such as conservation R&D, fossil energy development, or high energy physics. This system is similar but not the same as the budget and reporting classifications. See also Appendix A. Also, ERDA had developed classifications set forth in the "Uniform Contractor Reporting Guidelines", which, though not fully adopted within the agency, had a set of general technology categories, including fossil fuels, solar, conservation, nuclear etc. Again, though not an agency standard, a classification structure for energy R&D was used in the agency-sponsored "Inventory of Energy R&D Projects" conducted by Oak Ridge National Laboratories. (See also Appendix A.)

ERDA also supported a Technical Information Center at Oak Ridge which has developed an Energy Data Base (EDB) which is a computerized bibliographic information system. Information is classified into three general types: (1) devices, e.g. nuclear power plants and advanced automotive propulsion systems; (2) energy sources, e.g. petroleum and geothermal energy; and (3) scientific disciplines, e.g. chemistry and physics.

The Federal Energy Administration (FEA) also, previous to merging into the DOE, had established categories of energy activities in the Federal Energy Information Locator System (FEILS) under the National Energy Information Center (NEIC). The system is primarily based on energy stages subsumed under energy sources. For example, exploration, extraction, R&D, and other elements under coal; milling, storage, waste management, R&D, and other elements under nuclear; and so forth. Also available from the NEIC is a capability of access to a series of descriptions of energy-related data bases, input forms, and output reports. (See also Appendix A.)

The above serves to confirm the lack of a single, centralized, or comprehensive system for classifying energy activities and/or those programs carried out by energy agencies. It is likely that the adoption of one or more central systems will be accomplished in the near future. The problems involved in merging several Federal organizations with several rationales or philosophies will alone create difficulties in adopting standard systems or classifications.

A system of relevant classifications is needed nevertheless for a manpower assessment activity. It would appear at this juncture that as a preliminary or temporary measure that a taxonomy on energy activities for the manpower information system should be based on the current budget and reporting classifications.

D. CATEGORIES OF RELEVANT MANPOWER

As indicated, the primary focus of the Comprehensive Energy Manpower Information System (CEMIS) is on manpower in energy research, development and demonstration activities. However, the current as well as future manpower supply-demand balances can only be examined in the context of manpower in all types of energy activities and in all activities and in all sectors of the economy. In the following enumeration we have indicated the several categories which should be established in order to provide clearly for all possible segments of both the supply of and demand for those personnel required for carrying out the Nation's energy RD&D programs. These categorizations would also serve to define and delineate non RD&D areas of energy activities relevant to all possible areas of concern to the Department of Energy. These categories are grouped in the three parts shown to distinguish the energy activities (RD&D and other) and the remainder of the economy. However, the several categories would be regrouped for purposes of a particular data collection or in other ways for special analyses. For example, for a survey covering STP employment in all activities of the Department of Energy, categories IA, IIA, IIIA would be grouped.

Finally, it is of course not necessary that information be collected or analyzed in terms of all the categories indicated. This taxonomy is established to complete the entire universe of personnel relevant to the assessment of manpower in energy RD&D activities:

1. Energy RD&D, Scientific and Technical Personnel (STP)
   a. Department of Energy (DOE) intramural
   b. DOE: Government-owned, Contractor-Operated (GOCO's) and similar units
   c. Other DOE contract and grant programs

d. Other Federal Government
   i. Intramural
   ii. Contract
e. Other support (industry, universities, state government, etc.)

2. Energy Activity that is not RD&D, e.g. (U-235 production, weapons production)
   a. DOE intramural (STP)
   b. DOE: GOCO's, and similar units (STP)
   c. Other DOE contract and grant programs (STP)
   d. Other Federal Government (STP)
      i. Intramural
      ii. Contract
   e. Other support (industry, universities, state government, etc.) (STP)
   f. Non-RD&D occupations in energy industries (e.g., coal miners)

3. In Energy RD&D Occupations (STP), but Not Working on Energy
   a. DOE intramural in non-energy work, such as weapons R&D, high energy physics
   b. DOE: GOCO's, and similar units in non-energy work
   c. Other DOE contract and grant programs (high energy physics, space nuclear)
   d. All other employment in all other sectors (chemical engineers in pharmaceuticals)

E. OCCUPATIONAL GROUPS AND SPECIALTIES IN ENERGY RD&D

In broad general terms, the manpower information system for energy RD&D activities will be applicable primarily to occupations requiring long and/or highly specific training. These include scientists, engineers, technicians, selected craftsmen, and certain other management or professional fields. Furthermore, the occupations involved in energy RD&D are also found in non-energy programs, e.g. chemists, draftsmen, or boilermakers. However, even within fairly detailed categories of occupations there may be certain highly selective specialties which are required for the solution of unique energy RD&D problems. The subject of occupational classification has been intensively studied and developed, and different conceptual approaches and informational needs have produced a diversity of thought and usage. Three basic systems are currently in use, as well as several ad hoc systems that for the most part are elements of the three basic systems. These are:

1. Dictionary of Occupational Titles (DOT)*

This system was developed by the United States Employment Service (and its predecessors and State affiliates) for the operational objective of placing job applicants into jobs for which they were qualified. The classification applies to jobs potentially reportable by employers to the public employment service for filling by qualified job applicants and to applicants whose work experience is described and classified.

The system permits classification of jobs to a fine degree of detail on the basis of specific functions to be performed, the industrial and other location of the work, and the education, training and personal characteristics required of the worker to perform the work. The system delineates levels of progression in a job, from entry level to that of highly skilled and supervisory level. The overriding objective of the classification is to expedite and improve the function of job placement. Although other uses are recognized -- statistical aggregation for economic and social analysis and statistical analysis of historical trend -- these functions are in practice subsidiary to the job placement function. DOT usage is encountered therefore mainly in operational statistics of the public employment service, rather than in broad measures of employment.

2. Census Occupational Classification System**

This system relies on the descriptive content job titles given by respondents as well as their brief description of the work actually performed, but is geared to individual response by the worker and hence is subject to the varieties in conceptual approach that individuals have to the designation of their jobs and to the imprecisions in job labelling by workers who are unconcerned with the interests of classification. However, the system is primarily designed to be statistically aggregated for current and historical socio-economic analysis, and consistency and uniformity in job classification is a major objective.

*Department of Labor, Employment and Training Administration, Dictionary of Occupational Titles, Washington, D.C. 1977.

**Department of Commerce, Bureau of the Census, 1970 Census of Population, Classified Index of Industries and Occupation, Washington, D.C. 1971.

Even though the standard of work content is supposed to govern the classification of the occupation, there is a strong presumption that respondents tend to upgrade their job titles in reporting to the Census or Current Population Survey. Or, for similar reasons, the job title may be given in terms of the individual's vocational training or status, rather than in terms of the work content of a specific job in which he is employed -- especially in scientific and engineering occupations (NSF 14.) Studies by the Census Bureau have shown substantial imprecisions in occupational classification. However, errors and imprecisions in occupational classification are by no means restricted to the Census system or to responses by individuals, and any judgment on Census occupational survey or definitional problems needs to be made in the pragmatic context of a wide range of difficulties affecting all of the systems of occupational classification.

3. Standard Occupational Classification System (SOC)*

This system is being developed under the aegis of the Office of Management and Budget to provide a single acceptable alternative to other systems for statistical purposes by using the strongest elements of the DOT, the Census, and other systems, and providing bridges for converting their terminologies or aggregating their subsidiary detail. It relies heavily on aggregation of the fine detail of the DOT to classifications suitable for socio-economic analysis. These summary categories are at the same time largely consistent with Census nomenclature. Extensive effort has been made to achieve convertibility of the Census and DOT systems within the SOC. The SOC at this point remains a system in draft form that is still subject to general adoption in the statistical system and the pragmatic test of use. However, the careful work that has gone into making the SOC suitable for general use as well as compatible with the other major systems suggests that it may indeed become the Federal standard which was foreseen for it.

4. Other Systems

The National Science Foundation's occupational classification is largely related to the Census (which, for scientists and engineers, is close to that of the DOT). It is, however, modified on an ad hoc basis for special needs. In terms of emphasis, there is perhaps some predisposition for survey

*Executive Office of The President, Office of Management and Budget, Standard Occupational Classification Manual (Draft), Washington, D.C., 1976.

respondents to classify the vocation than to classify the content of the job. This involves the quite legitimate interest in the quality of the human resource, including education and credentialling, rather than in the components of the work performed. Moreover, for some statistical purposes, this approach seems to be the most practical, as for example the linkage of manpower demand (expressed in terms of expenditures by field of science) to the manpower resource (also described by field of science). There appears to be no major incompatibility, however, in NSF survey aims which involve direct reporting on occupational employment.

The Bureau of Labor Statistics (BLS), in its project to develop annual employment estimates of scientists, engineers, and technicians for the National Science Foundation, will provide selected occupational detail based on those used in its Occupational Employment Survey. The occupations to be included are very closely aligned to those included in the Standard Occupational Classification System (and are similar of course to those found in the Census and DOT Systems).

The National Research Council is even more concerned with the education and identification of the individual, and in their rosters and surveys of Ph.D. scientists the classification systems relate strongly to academic disciplines.

As noted before, the major occupational classification systems agree more than differ in their classification of the scientists and engineers involved in energy RD&D. There are great differences in the classification of craftsmen and semi-skilled technicians.

It is believed that the SOC will eventually become the paramount system for classifying energy occupations. Therefore, it is recommended that any modifications made for the purpose of securing further detail or for producing information for special needs should explicitly be made consistent with the SOC.

First, the generally accepted broad occupational categories of scientific, technical, and related personnel should be set forth. These are the occupational groups within which those working on energy RD&D and other energy activities are found. Then, the more exotic, detailed, or rare specialties, unique to energy RD&D, can be delineated within these broader categories.

The following list of very broad occupational groups, supplemented by the more detailed list shown in Appendix A, covers all scientific and technical personnel (including managers) possibly involved in energy RD&D activities. The list was constructed after reviewing available data sources containing occupational detail and interviewing officials of ERDA (headquarters and field) and other agencies. We sought to identify occupations or specialties involved in various energy RD&D programs, especially those specialties of a new or unique character. We were aided in this effort by a doctorate scientist formerly involved in energy R&D.

Engineers and Scientists (including college professors and instructors)

- Engineers
- Physical Scientists
- Mathematicians & Statisticians
- Life Scientists
- Social Scientists
- Health Professionals
- Architects
- Technicians and Technologists
- Administrators and Managers, Technical
- Skilled Craftsmen

The above list of occupations serves to illustrate the broader set of categories relevant to energy RD&D. This isn't to say that this specific set of categories would be used in all or any specific data collections. In some cases the list would be collapsed and in others expanded in detail. In any case, it is inclusive of the STP occupational specialties found to some degree in energy activities.

F. FIELDS OF DEGREES AND ENROLLMENT IN HIGHER EDUCATION

The major source of supply for scientific and technical manpower is the nation's system of universities and colleges. The categories under which students are enrolled or under which degrees are granted are the conventional fields of knowledge or instructional programs used by most of these institutions. Although such a classification is not occupational in the sense of describing work activities, it is related to occupational categories in designating the training usually associated with given occupations, especially the scientific and technical. The education and training of the professional scientist or engineer encompass a wide range of subjects and techniques, and the field in which he is awarded a degree does not adequately describe the breadth of education received. This taxonomy is therefore only useful in roughly identifying the potential energy manpower supply from new degree recipients and academic enrollments leading to degrees.

For describing the characteristics of persons working as scientists or engineers, academic degrees are also significant. They show the level and kind of education received whether or not directly related to occupation. Recognizing that a person's field of academic degree and occupation are often different, employers still try first to recruit new workers from among similar academic degree holders.

Academic degree classifications and fields of enrollment most generally in use are included in the National Center for Education Statistics (NCES) sponsored "Taxonomy of Instructional Programs in Higher Education." (OE-50064, 1970). This classification is primarily intended to provide a framework for collection of degree and enrollment data from institutions of higher education. Intended for universal applications, fields of academic study are relatively detailed with more than 300 fields grouped into 27 broad categories.

Other classifications of more limited use include the one developed by the National Research Council (NRC) for the Doctorate Records program and the system used for the National Sample of Scientists and Engineers by Census/NSF. Both relate primarily to science and engineering degrees. The former reflects a level of detail associated with its use to classify research degrees. The National Sample system is less detailed than either the NCES or NRC classifications, but is more similar to the former in structure. Although similarities among all three of these systems outnumber the dissimilarities, significant variations do occur. Occasionally the more detailed academic fields fall into different major groupings.

We believe that an abbreviated taxonomy compatible with and adapted from the NCES would be the most useful system for DOE use in classifying fields of academic degree and higher education enrollment for energy RD&D manpower analysis purposes. Most of the relevant data now follow the NCES system. If additional detail were needed for particular surveys, this abbreviated list can be expanded to the NCES taxonomy and if necessary even finer detail can be added from the NRC doctorate surveys. The following is an example to show how such a very abbreviated system featuring energy manpower training and drawing heavily on the sciences and engineering might look. See Appendix A for the fuller taxonomy, a listing of technological and occupational curricula (for awards below the baccalaureate) and the taxonomy for doctorates used by the National Research Council.

Taxonomy of Fields of Academic Degrees and Enrollment

Life Sciences

- Agriculture, including forestry and conservation
- Bacteriology
- Biochemistry
- Biophysics
- Botany
- Radiobiology
- Other

Computer and information sciences

Engineering

- Chemical
- Petroleum
- Civil
- Electrical and electronic
- Mechanical
- Industrial
- Metallurgical
- Materials
- Mining and minerals
- Engineering physics
- Nuclear
- Other

Architecture

Mathematics

Mathematics

Statistics

Other

Physical sciences

Physics and astronomy

Chemistry

Earth sciences (geology, etc.)

Other

Health professions

Social sciences

Economics

Psychology

Other

Other academic subdivisions (education, business, arts, humanities, etc.)

Mechanical and engineering technologies

Natural science technologies

Data processing technologies

Health services and paramedical technologies

Other technologies and occupational curricula

G. PHYSICAL LOCATION OF ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION

As indicated above, energy RD&D or other related energy activities can be carried out in a variety of locations. The more obvious descriptors of this type include political subdivisions and groupings of these into socio-economic areas. Thus RD&D is undertaken in the various States and territories (for which an obvious taxonomy exists) and for cities, towns, etc. and also in what are termed Standard Metropolitan Statistical Areas (SMSA's). The latter set of categories is clearly established in terms of reporting of various socio-

54

economic, commercial, and even scientific and technical data. Obviously, the CEMIS should utilize standard location categories: States, counties, cities, and SMSA's for such data as are required.

It may be possible that a future need may develop data categories which refer to location of activity but for which different taxonomies are desirable. These could include certain generic descriptors, such as on-shore/coastal/off-shore; above ground/underground; foreign/domestic; laboratory/field; western/eastern/Alaskan; and so forth. Development of such categories should await a more clearly perceived need for them.

H. INDUSTRIAL LOCATION OF ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION

Energy RD&D also can be characterized in terms of the specific industry in which it takes place. For most informational purposes, the Standard Industrial Classification (SIC)* coding system (developed by the Office of Management and Budget) is used. The use of this standard system is important since nearly all industrial data are gathered and presented on this basis. In this system, each establishment** is classified by its primary activity in terms of sales, within a two-, three-, or four-digit code, relating to the degree of industry detail.

One of the first problems encountered is to identify energy activities. Some activities are clearly "energy-related"; this includes the basic industries that extract fossil fuels, transport them, process them if necessary, or convert them into electricity, and distribute the fuels or distribute electricity. Specifically a list such as that developed by Folk and his associates*** includes such industries as:

*Office of Management and Budget, Standard Industrial Classification Manual, Washington, D.C., 1972.

**"...an economic unit, generally at a single physical location, where business is conducted or where services or industrial operations are performed..." (factory, mill, school, store, mine, laboratory, or central administrative office).

***Hugh Folk, et al., Scientific and Technical Personnel in Energy-Related Activities: Current Situation and Future Requirements, Center for Advanced Computation, University of Illinois, Urbana-Champaign, Ill., July 1, 1977, p.4.

Coal mining and associated services, SIC 11,12

Petroleum and natural gas extraction, SIC 13

Uranium mining and milling, SIC 1094

Petroleum refining, SIC 291

Products of petroleum and coal n.e.c. (fuel briquettes, coke, etc.), SIC 299

Fissionable materials production, SIC 2819 (part)

Coal unit-train, SIC 4011 (part)

Oil and slurry pipelines, SIC 4612, 4613

Electric and gas utilities including gas pipelines, SIC 491, 492, 493

Steam supply, including geothermal, SIC 496

Even in these industries some non-energy related work (including RD&D) goes on: in the petroleum refining industry, for example, research is conducted on chemical by-product uses of petroleum. (On the other side, "non-energy" industries may conduct energy-related research, as would be the case if the sawmill industry were studying the use of its waste products as fuel).

It is in identifying industries that contribute (purchases, technical support, etc.) to these basic energy industries that difficulties arise. The problem is in part a basic conceptual one of distinguishing some energy-related activities from non-related activities, and in part a practical one of developing economic information following an appropriate definition. Furthermore, the RD&D activities of a firm are not deployed in the same manner as its other activities.

1. <u>Conceptual Problems</u>

One problem is presented by multi-purpose aspect RD&D that may have implications for energy and also for other end-uses. For example, research on corrosion is required for advancing geothermal energy extraction, research on the propagation of wild grasses is needed for rehabilitation of open-pit mining areas. When <u>production</u> is considered, it is possible to identify as energy-related any industry more than a certain percentage of whose product goes to basic energy industries. But there is no way of measuring how much one or another kind of RD&D contributes to energy and to other activities. The interrelationships of science and the potential relevance of research in any field or subject to any other field -- especially so broad a field as energy -- is so well accepted that the point does not need to be labored.

2. Practical Problems

From a practical point of view the problem of definitions is compounded because the statistics on production, employment, shipments, sales, etc., are compiled on the basis of company units or establishment units, and the units are often engaged in a variety of activities of which energy-related ones are only a part. So in most economic statistics the energy-related activities are not segregated from others. If a group of industries is identified as being "energy-related" on the basis that more than a certain proportion of its work is energy-related, regularly published statistics on its production, employment, etc. can be used as a crude measure of activity and employment related to energy, but it would not be a true measure of employment or production in energy activities *per se*, since it includes non-energy-related activity.

It is possible to ask industrial firms or other employers for separate data on their energy-related activities (this is done for example, in the Census/NSF annual survey of R&D in industry). Since the concept of "energy-related" often is not clear-cut, different firms will give answers based on varying understandings of the concept, unless a clear definition is given in the questionnaire.

An an alternative to getting this information from employers, it can be asked of individuals, as in the case of the sample surveys of Ph.D.'s by the NRC, or the post-censal surveys of scientists and engineers by NSF/Census. While the official of an institution -- company, university, etc. -- has to assemble information on employees in terms of the projects they are working on, the individual employee can more readily report on his own activity, given the same definition of "energy-related" work.

In developing a definition of "energy-related" activity, a first recourse is: any project the DOE supports. But the DOE does not regard every research project it supports as energy-related, since it supports some military applications and some basic science projects. With exceptions such as these, DOE can define its fields of energy interest and can collect data from its contractors or the recipients of its support on the employment and costs associated with its work.

There is a substantial amount of energy-related RD&D, as well as production, operations, construction, etc., that is not supported by DOE, but is conducted by private industry with its own funds, or by professors and graduate students, either without project support or with funds from industrial firms, foundations, State or local governments, etc. In these cases, collection of data on energy-related research runs into the conceptual and definitional problems mentioned above.

While RD&D activity cannot easily be identified as energy-related on the basis of the industry or type of establishment in which it is conducted, it is possible to identify industries as more or less energy-related on the basis of the relationship of their production to the energy economy -- the proportions of their sales or product that go, directly or indirectly, into clearly basic energy-related industries such as those listed above (those directly producing, converting, and distributing energy). An input-output table for the U.S. economy, developed by the Department of Commerce, shows what proportion of each industry's output goes to every other industry.* This table, and records of the materials purchased for energy facilities construction, were used by Folk and his associates to identify a list of 29 "indirect energy industries"** (See Appendix A). The list includes some industries making equipment only a small part of which goes to energy industries, but some of which is used by consumers, government and other business firms for non-energy uses. An example is the fabricated plate works (boiler shops) industry, which makes both equipment for electricity generation and tanks for storage of chemicals, gases, etc. In this exercise much depends on the level of detail in which the input/output information is summarized. A very small part of some sections of the machinery industry division's product goes to the oil, coal mining, petroleum refining and electric and gas utilities industries, but a larger proportion of the output of specific component industries, such as the turbines and steam engines industry, the motors and generators industry, the oil field machinery industry and the mining machinery industry, goes to these energy-related industries.

*Department of Commerce, Bureau of Economic Analysis, Input/Output table of the U.S. Economy, 1971, Staff Paper #28, March 1977

**Folk, op. cit. p.5

However, for purposes of a manpower information system for energy RD&D -- for which the aim is to identify industry sectors in which RD&D is being conducted on energy and its generation, conversion and conservation -- the use of a list of industries that sell a substantial part of their products to the basic energy-producing and converting industries may miss some important sectors. The list developed by Folk includes the screw machine products industry, for example, presumably because it sells to the basic energy industries, but it is reasonable to guess that not much research on energy goes on in that industry. On the other hand, the list omits some industries making energy-conversion or conservation products that are sold, not to basic energy industries, but to consumers and to other industries, and it is reasonable to believe that much of the research going on in these industries is related to energy conversion efficiency or energy conservation. Such industries include: mineral wool, SIC 3296; internal combustion engines, n.e.c., SIC 3519; air conditioning and warm air heating equipment and commerical and industrial refrigeration equipment, SIC 3585; storage batteries, SIC 3691; primary batteries, wet and dry, SIC 3692; and all transportation equipment, SIC 37.

To get a total picture of energy RD&D activity, sectors such as those listed above should be added to the list of "indirect energy" industries developed by the Folk study.

Another attempt to develop a list of energy-related industries using input/output information was made by an ERDA-American Society for Engineering Education Task Force.* It included every industry, one percent or more of whose output went directly or indirectly to the direct energy producing industries -- coal mining, crude petroleum and natural gas extraction, petroleum refining and electric and gas utilities. Twenty-two industries were included -- a different list than that developed by Folk and his associates. Included are such industries as wholesale trade, banking, advertising, railroads, real

*ERDA-ASEE Education and Training Task Force for the Assistant Administrator for Institutional Relations, A Proposed Plan for Education and Training in Non-Nuclear Energy Technologies, February 1977, pp. 87-89.

estate -- not normally considered as energy industries -- because they met the one-percent test. Also industries were excluded that do not sell to the basic energy industries at all, but whose products are involved in energy conversion by consumers; this results in an incomplete and unuseable list, particularly for RD&D activities. (See Appendix A.)

In summary, it might be desirable to collect and analyze data on energy RD&D (and even other energy activities) on the basis of the industry in which such activity is conducted. Nearly all economic data to which energy RD&D activities (not supported by the Government) could be linked (production, shipments, employment, sales, etc.) are gathered and maintained on an industry basis and it is categorized by the SIC codes. However, the principal activity with which the Comprehensive Energy Manpower Information System is concerned is energy RD&D. From the discussion
ceptual and practical difficulties exist in classifying industries as being energy-related for RD&D activities, beyond the basic energy industries shown above.

Therefore, DOE may engage in data collection itself or support or utilize other sources which include categorization by industry. However, there appears to be no way to specify an industrial taxonomy for collection of data on energy RD&D, other than the basic energy industries.

CHAPTER III

RATIONALE AND ANALYTICAL FRAMEWORK

A. INTRODUCTION

The purpose of this chapter is to describe the rationale and analytical framework for the task of identifying and evaluating manpower information relevant to energy RD&D, and to show how such information may be used in a systematic fashion to meet the needs of DOE.

The chapter will first discuss the supply of energy RD&D manpower, identifying the critical elements and the factors affecting them, the kinds of analyses that may have to be made, and the data required for such analyses.

It will then discuss the demand or requirements for energy RD&D manpower in the same terms.

A third section will deal with the measurement of the balance of supply and demand.

B. MANPOWER SUPPLY SOURCES AND LOSSES

1. Introduction

The supply aspect of a manpower information system is concerned with the numbers and characteristics of individuals engaged in the given activity plus others qualified for future engagement in the activity, including some who were previously so engaged. The system should include information on the entry routes into the activity and the exit paths from it, and the numbers of persons entering and leaving, and should include data on supply sources in preparatory training, patterns of occupational mobility, and working conditions that may affect these patterns. Within the system should be information on the current situation, as well as the basic data which permit the assessment of probable future situations under given assumptions.

2. The Manpower Supply Pool

a. Numbers and Characteristics of Those Presently Employed in Energy RD&D

i. By energy sources - Energy RD&D programs differ from each other in subject matter, method, financing and staffing characteristics. Furthermore, the programs impact on different interest groups in quite different ways. Therefore, the system should provide information on important discrete energy sources, such as coal, petroleum, solar, geothermal, etc. This will permit assessment of the several energy programs in terms of staffing progress and deployment of manpower resources.

ii. By occupations and industries - Energy activities are carried out by workers engaged in many different occupations and in numerous industries. Many of these occupations are among those requiring the highest levels of scientific and technical expertise, the attainment of which has traditionally involved a long period of education and training. For example, the high energy physicist engaged in fusion R&D will probably have academic training through the doctorate level, supplemented with several years experience and training in research. Other specialized occupations may involve similar or shorter training periods, but RD&D energy activities in general usually require more workers possessing job skills of higher levels than most other broad activities. Then, too, these occupations range across a broad spectrum of scientific (e.g. chemist, physicist, earth scientist, etc.), technical (most, if not all, engineering and technician fields) and craft (e.g. construction, mining, manufacturing, etc.) skills.

Similar energy activities of interest are located in a number of industries, which include such disparate locations as generation and transmission of power at public utilities, nuclear research at universities and associated research institutes, or pilot plant construction for oil shale processing. Furthermore, the nature of DOE interest in given RD&D establishments will vary depending on DOE's administrative responsibility for them.

The DOE, since it is charged with oversight of specific energy programs, in order to note present and anticipate future production problems, must be aware of the nature and deployment of manpower resources as well as energy output. Education and training facilities must be considered with a view to the current manpower pool as well as anticipated manpower demand. The complex occupational and industrial mixes in energy RD&D imply training programs featuring both breadth and specialization.

iii. By personal characteristics - Such personal characteristics of the energy manpower pool as age, sex, and minority origins are important elements of the information system.

The average age of the work force, for example, provides insights into the balance between the younger (presumably less experienced) and the older (more experienced) groups. Such information provides clues as to what types of training to encourage, emerging retirement problems, and recruitment policies.

The emergence of new patterns and policies applying to labor force participation by women places an importance on separate information by sex. Women are an increasing proportion of many work forces, approaching 40 percent nationally. As additional personnel resources, their participation is encouraged; since they are characterized by dissimilar work history patterns, separate information on their participation is desirable.

With the growing commitment to a national policy of equal employment opportunity, it becomes necessary that information be available on minority groups for nationally important industries, and particularly for activities subject to the degree of public scrutiny and control as energy. Currently, separate information on the currently employed is needed for such minority groups as blacks, persons of Spanish origin, Asians and American Indians.

iv. Education and training - Probably the most useful indicators of education and training requirements for the energy workforce are those which show the types of training possessed by those currently engaged in the activity. This information identifies the training of workers who are able to perform the work, and supervisors are likely to seek new workers with the same training. Education and training programs for new workers are usually patterned after the experience of present workers, although workforce flexibility readily makes for exceptions.

Information elements relate to the type of institution providing training, and the occupational nature, length, and recency of training. For higher education recipients, highest degrees attained are useful indicators and are particularly important for RD&D activities.

v. Location - Although energy activities are of the highest national importance in the aggregate, many of them are performed essentially as local or regional industries, as for example, geothermal exploration or solar energy development. Summary national manpower data should be supplemented by regional and, in many instances, state data for at least those states where important installations are located. The broad responsibilities of DOE are administered along regional lines, and some energy activities are regulated by state agencies.

b. Other Qualified Manpower Supply

Although some specialized skills may be unique to energy RD&D, few, if any, occupations are found exclusively in such activities. Rather, these occupations form part of larger universes, and exist in many activities and industries. For example, of 38,800 chemistry doctorates included in a National Research Council survey in 1975 only 7 percent were engaged in energy R&D and 36 percent in all R&D. Doctoral engineers engaged in energy R&D form a somewhat larger proportion of the doctoral engineers engaged in R&D (NRC 2).*

Those in scientific and technical occupations not currently involved in energy activities may be considered, in a sense, to constitute a labor reserve, an unknown part of which could become part of the energy workforce under certain conditions and incentives. Within each such group, will be found some individuals qualified for immediate employment in energy, others with few of the required qualifications, and various gradations in between. Effective use of such a supply is limited by considerations of training and retraining, the location of employment opportunities, current work activities of this reserve, working conditions, and incentives necessary to rechannel workers into different activities.

The implication for the manpower information system is that the system should provide information on this reserve for at least those occupations likely to be in short supply. The information should be sufficient to make a judgment on the feasibility of recruitment to energy employment if needed. Desirable information for this group includes occupational qualifications; type, length, and recency of training; current work activities; and location.

3. Education and Training Relating to Manpower Supply

a. Institutions and Types of Training in Target Occupations

Important to the understanding of manpower supply for a given activity,

* References in parentheses are to sources listed in Appendix B.

is information on the process by which the supply is created, in other words, the education and training system which instills the occupational and other skills necessary to function effectively. Such information includes types of training institutions, locations, their curriculums, and the extent to which their students successfully adapt to the work demands of the real world.

For energy activities, especially RD&D, institutions of higher education are particularly important for the professional scientific and technical training provided. Graduate schools award advanced degrees, and engineering schools most of the technical degrees. Technical institutes are an important source of science and engineering technicians, as are community colleges.

Trade and technical secondary schools also provide training for technicians and craftsmen, frequently as the basis for more advanced subsequent training. Numerous other, generally less structured, training opportunities exist in the forms of apprenticeship, industrial on-the-job, armed forces, etc. Most frequently these provide training for craftsmen and technicians.

Since, for the most part, education and training of this character are not without cost to the recipient, the costs incurred are relevant information for supply considerations. In the same way, fellowship, scholarship, and other incentives for a particular type of training may be an important consideration for supply.

b. Enrollments and Completions

The potential augmentation of the manpower supply is measured by the flow of students through the training process for those occupations which are normally recruited from those sources.

For the professionally trained scientists and engineers, degrees granted by the universities and colleges at the several levels in science and engineering measure commitment to science or engineering occupations progressively as higher degrees are received. Enrollments in similar curriculums indicate possible future supply increases after adjusting for academic attrition. Science and engineering occupations of interest to energy activities tend to emerge from a relatively small number of academic curriculums, such as nuclear, electrical and electronic, petroleum, chemical engineering, and the physical sciences. One of the tasks of the manpower specialists will be the identification of curriculums which are especially productive in training for work in energy.

Information on completions and enrollments for trade and technical secondary schools, apprenticeships, industrial, armed forces, and other training is less satisfactory as an indicator of potential supply on a broad national or regional basis and also much less complete, but may be useful in given local situations. Training quality varies greatly, and content is sometimes highly specialized to develop workers for specific jobs.

c. Projections of Future Enrollments and Completions

In assessing the prospective supply in the occupations involved in energy RD&D to meet future demand or requirements, projections of the inflow into these occupations from education and training programs are needed.

The National Center for Education Statistics publishes projections of total college enrollments and degrees, and of degrees by field of study, typically for about 10 years into the future.* The NCES defines these as projections based on expected changes in the population of college age (all of whom have already been born at the time the projection is made), and on recent trends in enrollment rates, retention rates, and the choices of course of study that students have made. They are mathematical extrapolations of trends, not forecasts or predictions, the NCES says. They may be described by saying this is what is likely to happen if people keep on doing what they have been doing and nothing happens to make them change their behavior.

In reality, things do happen: the attitudes of youth toward going to college and towards the kinds of work they want to do, or the subjects they want to study, do change. Among the factors that affect these attitudes are not only social changes, and changes in life styles, but also economic changes, rises or declines in the business cycle and unemployment, the growth or decline of industries, changes, and shortages or oversupplies in certain occupations,

* Department of Health, Education, and Welfare, National Center for Education Statistics, Projections of Education Statistics to 1985-86, NCES 77-402, Washington, 1977.

which are reflected in the attractiveness of salaries paid. Students react to these influences, partly on the basis of information from the government or other sources on the employment outlook. In fact, such information is issued expressly to help young people to avoid overcrowded fields and enter those with better employment opportunities.

The NCES projections may turn out to be poor as predictions, but they serve an important purpose: taken together with projections of requirements for workers in each occupation, they illustrate what would happen if students did not change their past patterns of enrollment or course selection -- shortages would occur in certain occupations, oversupply in others, and a rough balance between graduates and job opportunities in still others. On the basis of this information, two kinds of adjustments may be made: students may shift their courses of study, and employers may adjust their employment policies, insofar as they have flexibility, to use more workers in the occupations that may be in oversupply -- and therefore cheaper to employ -- and fewer workers in the shortage occupations. An accurate estimate of actual demand and supply in the future year would therefore reflect both these types of adjustments.

Projections of graduations are also made by organizations other than NCES -- the National Science Foundation, for all levels and fields of scientific and technical education, and some of the professional societies for members of their own fields.

d. Training Attrition

The success of the training institution -- and of the trainee in completing an assigned curriculum -- reflects the effectiveness of the training process in augmenting the manpower supply. Normally, about half of the students enrolling in four year engineering curriculums fail to complete them. Other shorter training programs may not be much more successful.

The moral for manpower supply information is that it is necessary to adjust for the loss in the training system in order not to overestimate potential supply. Information on attrition should be sought for occupations which are likely to present critical supply problems.

4. Work Force Mobility and Attrition

a. Immigration and Emigration

Traditionally, the domestic work force has been greatly expanded at all levels of skill by immigrants, mainly from Europe and Africa, and now many from Asian countries. Legal restrictions now limit the numbers of immigrants and within such numbers encourage immigration of occupational skills found in short supply within our country. Although unlikely to become a major source of supply for energy manpower in the near future, immigration of scientists and engineers may be important in selected RD&D occupations. Immigrant visa information now provides occupational data.

Similarly, emigration of energy manpower represents a loss to the manpower pool of unknown proportions. Foreign citizens now constitute a significant proportion of the engineering graduates; many of whom return to their native lands on completion of training. With the development of foreign and international energy programs, such emigration of professionally trained personnel might well increase. No satisfactory measurements now exist, although partial information can probably be developed through the records of other countries that identify the U.S. as the country of origin of their immigrants.

b. Occupational Mobility

Another important determinant of manpower supply in an occupation is the extent to which workers move into it from other occupations for a plus, or move from it to other occupations for a minus. Such movements are characteristic of the flexibility in our system in contrast with more structured systems in some foreign countries. Such mobility may be in response to the labor market, industrial conditions, or personal considerations.

Mobility with respect to energy manpower implies a broader definition of movement into and out of an activity, since it would regard as a loss to the energy manpower pool, for example, the engineer who moved from developing a bituminous coal mine to a similar position in iron ore mining to be employed in the same occupation, but in a non-energy activity.

c. Age-sex Composition of the Supply

The age distribution of the work force may provide clues as to future loss through retirement and deaths. Since the patterns of labor force participation are different for males and females, separate distributions are desirable. A comparison of such age-sex work force distributions with life tables for the population and retirement tables for occupations may reveal manpower supply losses indicated for the future.

5. Working Conditions Affecting Supply

Working conditions affect labor supply through encouraging workers toward activities considered attractive and away from those believed less attractive. In a competitive market situation, workers will seek employment where the sum total of wages, fringe benefits, hours of work, and other conditions are considered superior to the competition. High labor separation rates may indicate dissatisfaction with working conditions. Those responsible for energy programs should be familiar with such indicators of conditions as noted below.

a. Salaries and Wages

The labor supply concept implies a level of compensation -- wages and salaries -- for a given occupation, industry or activity. In economic terms, the supply is the amount of a good (labor) offered at a given price (wage). Wage levels can be said to be the most important determinant of the size of the supply.

Useful wage information includes occupational averages for energy activities which will permit comparisons with competitive activities. Wage data are usually expressed in terms of hourly or weekly averages for production and clerical workers and monthly or annual averages for professional and semi-professional. Sometimes entry wage rates are more significant than averages, since the most mobile workers are likely to be the youngest and those coming out of school and choosing their first jobs.

b. Labor Turnover

The measurement of entrances into and exits from the employed labor supply, or labor turnover, are usually expressed in terms of hires and separations, calculated as percentages of the number employed. Such labor turnover data provide measures by which success in attracting, maintaining or reducing the work force may be judged. To the extent that workers leave the labor force or move to non-energy activities, turnover measures net loss to the manpower pool.

c. Industrial Hazards

Workers, who have long been aware of the diseases and accidents associated with industrial operations, and the public, who have more recently become aware of them, are now joined to eliminate and alleviate them. High injury frequency rates serve both to discourage workers from entering hazardous activities and to increase compensatory costs. Remedial programs in large part depend upon analysis of the extent and causes of such diseases and accidents.

d. Industrial Unrest

The information system requires elements which will bring to the attention of management such symptoms of industrial unrest as labor grievances, disputes, work stoppages and the like. Such conflicts reduce the effectiveness of the labor supply in the same fashion as a loss of workers. Finally, progress of unionization and collective bargaining provisions in energy and related activities are useful indicators of probably future trends of administrative value.

C. DEMAND OR REQUIREMENTS FOR MANPOWER

The concept of requirements is used instead of that of demand, especially in connection with assessment of the future. Requirements is defined as effective demand associated with expected, stipulated or assumed changes in the major factors affecting demand, and under the assumption of no substantial change in the relative price of labor -- wages or salaries. The actual demand at a future time can only be estimated at a second stage of approximation, after the prospective requirements and supply have been estimated and compared; if there is an imbalance, its effect on salaries can be estimated and the secondary effect of such salary changes on both demand and supply evaluated.

This section will review the factors affecting requirements for energy RD&D manpower, and suggest analytical approaches to their measurement, understanding and use in assessment of present and future requirements. The major factors are government programs, policies and budgets affecting energy RD&D, the demand generated by the economic activity of the industries or other sectors employing energy RD&D workers, changes in energy economics, and demand for teachers.

It should be emphasized at the outset that research is conceptually one of the most difficult of economic activities to project for the future. This difficulty arises out of the role of research as the forerunner of technological innovation. In making economic projections, we generally rely on the persistence of pattern in economic life. Families buy automobiles, so the growth in population and in income levels can be used to estimate the number of automobiles sold; making automobiles requires machinists, assemblers, engineers, and so on. But an activity whose function is to break past patterns by discovering new products or new technologies, and one in which breakthroughs open new avenues for further research and development cannot easily be projected, in spite of the many attempts to systematize "technology forecasting." At best, one can see whether an industry or company has a persistent pattern of allocating funds or resources to R&D -- a stable percentage of sales or employment -- and, finding this, one may assume a continuation of this pattern.* But the exact nature of the R&D -- whether in energy or in other fields -- may shift with the scientific breakthroughs and with economic changes that change the pay-off prospects of different areas of research.

I. Government Plans, Policies and Budgets for Energy RD&D

Plans and policies both on energy production and on energy RD&D affect the requirements for energy RD&D manpower, since they both give direction to efforts in private industry. Government funding of energy RD&D has a direct impact.

* National Science Foundation, 1985 R&D Funding Projections, NSF 76-314, Washington, 1976.

Plans and policies on energy generally include controls, pricing, imports, extraction, pollution control, etc., -- all of which have implications for energy RD&D in private industry. In theory, these are supposed to be explicitly stated in Presidential energy programs, or such programs as the national plan for energy self-sufficiency. The implications of different energy scenarios or policy choices on relative prices, taxes and other costs of doing business have to be analysed in the context of the changing general economy, and their effects on the growth of production and employment in the various sectors estimated. The terms in which they are stated will need to be translated into terms meaningful for manpower requirements analysis: i.e., the implications of policies will have to be quantified ultimately in terms of the numbers and kinds of energy RD&D personnel required in each sector of the economy or energy technology in which they are employed.

Plans and policies on energy RD&D directly affect energy RD&D personnel. Proposed expenditures have to be translated into the kinds of personnel needed, by occupation or specialty. To do this, it is necessary to have ratios of employment, by occupation, to dollars spent for RD&D on each type of energy source or technology (since the kinds of occupations differ, depending on the technology), and also for research separately from development and demonstration projects, (since the proportion of costs represented by manpower, as well as the mix of occupational skills, may differ). Current or recent past ratios are not necessarily a firm guide to future manpower requirements, since the future direction of R&D may be different from that of the past -- particularly if breakthroughs occur that open up new areas of research and technology; but trends in these ratios may be a good starting point for projections.

The requirements for energy RD&D manpower in National Laboratories and Energy Research Centers and the requirements of contractors and grantees, including industry, universities and nonprofit research organizations, can be projected from estimates of energy RD&D budgets for each type of energy technology or by type of operation (e.g., national laboratory versus contract research), going as far into the future as forward budget planning permits.

2. The Level of Economic Activity of the Industries or Other Sectors Employing Energy RD&D Manpower

The level of business activity, profitability, decisions about future investment, and mangement's perceptions about the value and pay-off of conducting RD&D all affect the employment of energy RD&D personnel in each sector of the economy.

In industrial sectors, current demand for their product is shown by industrial production or activity measures, and prospective demand can be estimated by a variety of techniques such as those used by the Bureau of Labor Statistics in its economic growth studies.* These include projections of the growth of GNP and its composition, projection of the final demand for each type of product or service associated with this general economic growth, and estimation of the production generated in each sector of the economy, using the Department of Commerce input/output tables, or multiple regression analysis. Other econometric models may also be used to project specific industry demand associated with assumed rates of general economic growth or changes in specific sectors, (e.g., MIT-FRB, Wharton, Brookings). A study currently funded by the U.S. Department of Labor, still in process, is attempting to analyze the use of the major econometric models to forecast the impact on labor demand of various energy policies.**

Decisions about future investment are based in part on such projections of demand. Management's perceptions about the pay-off of RD&D are related to these factors, but also to the changes in energy economics discussed below. Government support of RD&D is also geared to some extent to projections of final demand for products and resulting requirements for expansion of existing resources or development of new ones.

The connections between changes in demand for products and RD&D expenditures -- generally and in each sector -- have to be explored by examining how

* The most recent projections are summarized in articles in the Monthly Labor Review for March 1976 (pp. 3-21) and November 1976 (pp. 3-22)

** Study by Albert J. Eckstein and Dale M. Heien under contract to the U.S. Department of Labor, Office of Research and Development, for "A Review and Analysis of Econometric Models of the U.S. Economy with Particular Reference to the Impact of Energy Policies on Labor Demand and Employment."

the two relate to each other over the years. This requires statistical series on dollar volume of production or sales and profit rates in the various industries and on RD&D expenditures by the industries. In view of the rising costs of energy, RD&D effort on energy efficiency or conservation may be increased regardless of changes in demand, production or profitability; i.e., the relationships shown by past experience could change. Similarly, the sources of energy used in various industries could change as a result of changing relative costs.

The effects of changes in RD&D expenditures upon employment of RD&D personnel may be estimated by developing ratios of employment to RD&D expenditure dollars. The trend in these ratios over time will be affected both by rising salary levels and by the changing cost composition of the RD&D activity that goes on: use of differing amounts of personnel, equipment, materials or other factors in research will affect these ratios. To get insight on these trends requires analysis of the RD&D budgets and employment of different sectors of industry. At educational institutions, government labs, and non-profit institutions RD&D is carried out either on grants or contracts or is self-funded, partly in the salaries of faculty members and university funds for assistantships. To estimate this type of demand, data are needed on RD&D expenditures and manpower in such institutions, and on the future amounts and directions of Federal support for energy RD&D in such institutions, as noted below.

In some cases it may be possible to collect projections of manpower requirements or RD&D activity from employing institutions directly, rather than by estimating RD&D expenditures. The experience in this kind of forecasting -- asking employers for their forecasts of manpower needs or RD&D expenditures -- has not been encouraging in the past, but may be necessary where no data on expenditures or manpower can be obtained.

3. Changes in Energy Economics

Beyond what goes on in individual industries, demand or requirements for energy RD&D funding and manpower are affected by the relationships among energy sources, including local, national and world supplies, prices and technologies affecting the use, efficiency, and costs of each energy source and competition among them. These developments affect the areas in which RD&D is done -- or, at least that part of RD&D which is not basic research -- and its direction and emphasis.

Efficiency and costs of each source, as well as adaptability to various uses, pollution considerations and strategic considerations (e.g., desire for self-sufficiency) relative to those for other sources are major determinants of the competitiveness of each source for energy generation and use. The ability to assess or forecast changes affecting competitiveness, therefore, requires the ability to assess the economic viability of each source and foreshadows decisions to initiate RD&D activity designed to make them more competitive.

Prices and efficiency may change with a wide variety of factors -- international relations, national policies, the extent of control by monopolies or cartels, war, catastrophes, discoveries of new fossil fuel reserves, technological innovation, relative prices, changing demand, etc.

In view of all these uncertainties, forecasting is difficult. To develop strategies for RD&D planning -- which determines manpower requirements -- it is essential to have at all times a provisional assessment of trends in relative costs of using various energy sources, subject to frequent revision. Such rough assessments may be useful in decision-making in cases where the cost differences among sources are large and decisive, but less useful when the cost differentials are small and small errors or changes in costs may affect the balance.

The effects of these energy economic factors can be translated into manpower implications only through the intermediary analysis of their effects upon economic activity and RD&D expenditures in each of the various economic sectors in which energy RD&D personnel are employed.

Thus, the assessment of future requirements for energy RD&D manpower would require a series of studies of the business (or level of operations) and RD&D activity of each sector of the economy as affected by all relevant developments in energy economics, as well as in demand for the products of several sectors.

4. Demand in the Educational System for Teachers

The need for training engineers, scientists, and technicians generates a requirement for teachers specializing in each subject field.

Theoretically, teacher requirements in each discipline are a function of the total numbers of students that have to be trained in each relevant occupation to meet the economy's total needs for trained workers. Practically, it doesn't work out that way, for several reasons. One is, that in the training of each type of specialist, teachers in more than that specialty are required -- physicists are taught by chemists and mathematicians as well as by physicists (not to mention professors in the humanities). A second reason is, that, in fact, the educational system is not planned on the basis of occupational training requirements alone, but also as a provider of a consumption good - education.

The aggregate manpower requirements for future energy RD&D specialists have to be examined to see if they place any special burden on the educational system. Other than this, the educational system's requirements for the various specialties can be estimated on the basis of an expected volume of enrollments (graduate and undergraduate) in the institutions. These requirements have to be added to the total requirements for these occupations generated by industry and government.

The teachers at institutions of higher education also engage in research, of course. For that research done on grants or research contracts, data on the funds provided and their employment impact are needed, as noted above in the discussion of government budgets for energy RD&D.

5. Summarization of Requirements for Energy RD&D Personnel

Current and future needs for energy RD&D manpower have to be estimated by analysis of the manpower requirements of employing sectors resulting from their own business activity and RD&D investment (or, in the case of colleges, enrollments), as these are affected by the changing economics of energy, and by government policies and programs.

This will require developing a picture of total energy RD&D expenditures, including government, industry, universities and research organizations, by energy source and/or technology, since this affects the occupations required. It will be necessary to develop time series on RD&D expenditures by areas of research (i.e., energy or technical field) that can be translated into occupations, source of funding, and type of institution (or industry sector) in which the work is done. These series can then be related to series on employment of the manpower involved, by occupational specialty; it would then be possible to develop estimated ratios of expenditures to personnel that would enable projections of manpower requirements to be made on the basis of RD&D expenditure projections. If there were enough consistent data over a period of years, it might be possible to observe a changing occupational composition of RD&D manpower in certain types of research, possibly reflecting change in the direction of research, or progress from research to development to demonstration.

For these energy RD&D occupations, the balance of supply and demand cannot be assessed unless demand arising from other kinds of employment is also estimated. What is required, therefore, is a comprehensive estimate of the manpower requirements for these occupations in all sectors of the economy in which members of these occupations are employed.

A critical issue is whether some sub-specialties engaged in energy RD&D are unique among the broader specialties, or whether members of the broader specialties are, in reality able to engage in, or are hired for, energy RD&D work. For planning the manpower system, therefore, it becomes important to identify energy RD&D specialties at the outset, as was done in Chapter II and in Appendix A.

D. MEASURING THE BALANCE OF SUPPLY AND DEMAND

Indication of the current and past market situation in each occupation -- the balance of supply and demand -- becomes important in analysis of present policy issues, determination of the existence of bottlenecks or problem areas, and in making decisions bearing on future measures to affect either demand or supply -- for energy RD&D or in general. Such indications may be gained from trends in relative salaries, the ease or difficulty experienced by workers in getting jobs, and by employers in hiring, unemployment, want-ads, quit rates, immigration, and employment service operating statistics. The point to be emphasized is that energy RD&D manpower supply/demand must be analysed in the context of the whole supply/demand situation for each occupation involved.

1. Relative Salaries

An element affecting demand for energy RD&D specialties is the cost of employing this manpower -- i.e., salaries in their occupations relative to those in other occupations. Data on trends in relative salaries are required, and also analysis of the wage elasticity of demand -- do employers substitute one specialty for another (technicians for engineers, for example) when relative salaries make it attractive, or are occupational mixes relatively stable regardless of relative salaries?

Relative salaries are also an important element affecting the supply of energy RD&D personnel, since workers are attracted into and away from occupations or fields of employment by relative salaries and other conditions of employment.

In developing such statistics, the concept of relative salaries is important. Inflation makes current-dollar figures less useful for comparison over time, and the salaries are best expressed as a relative to some broad average, such as that for all employed persons. The relatives for each occupation can then be compared to those for any other occupations, and comparisons can also be made for an occupation for different time periods. A narrower average, such as that for all professional workers, might be deceptive because the whole group of professional occupations might be affected by similar market conditions. If both engineers' and technicians' salaries are expressed as relatives to average salaries for all workers, each relative may be compared to the other.

Because of rigidities in salary structure within organizations, it might be better to use entrance salaries, if available, as the basis for comparisons, since they are more sensitive to market forces.

2. Other Indicators

The ease or difficulty in getting jobs is indicated by the placement experience of new graduates, and the earnings they receive. It is also shown by statistics on the unemployment rate and the average duration of unemployment.

Help-wanted advertising has been shown by the Conference Board to be a fairly good general indicator of fluctuations in demand, as shown by correlation with unemployment and job vacancy statistics.

Immigration and emigration data might reflect very favorable or very unfavorable employment opportunities and demand in the United States, relative to those in various other countries.

Difficulty in hiring qualified workers is shown by data bearing on the experience of employers in finding workers, and on job vacancies. Job placement services operated by professional societies, frequently in connection with their annual meetings, are sometimes a source of useful information on the relative numbers of job-seekers and job offers; many employed members of these professions use the services to seek better jobs, so not all the registrants are unemployed.

CHAPTER IV

ELEMENTS OF A COMPREHENSIVE MANPOWER DATA SYSTEM: EVALUATION OF EXISTING DATA SOURCES AND PROPOSALS FOR IMPROVEMENTS

A. GENERAL INTRODUCTION

The previous chapter pointed to the kinds of information that have to be taken into account in assessing current and prospective manpower situations and evaluating problems in energy research, development and demonstration programs. This chapter will review the available sources for each of these kinds of information, will evaluate the usefulness of each source for DOE's purposes, and will make recommendations of two kinds to specify the elements of a comprehensive manpower data system: what changes in existing sources would make them more useful to DOE; and what new surveys or organized sources of data are needed to meet DOE's needs.

The general viewpoint on which this chapter is based is that the establishment of the information system will face practical operating difficulties in data collection, partly a result of normal resistance to new reporting and partly arising from new and unique data specifications. We believe these difficulties can be minimized and reporting burdens reduced if DOE uses reasonable diligence to take advantage of existing manpower information systems so far as possible. The recommended system follows the premise that many of the established series can be adapted with some addition or revision to meet DOE needs without undue violence to other purposes served.

In general, we consider that DOE resources would better be employed in developing analytical expertise rather than in organizing a large statistics collecting program for energy manpower, but that it should exert an active influence on the statistical collection programs now going on, to make sure that they meet DOE's informational needs. This can be done by representation to the agencies engaged in surveys, to the NSF, which is the focal agency for science manpower statistics, and to the Office of

Statistical Policy and Standards of the Department of Commerce. It will also require some financial support to make possible additional work required to meet DOE's needs.

To accomplish these necessary changes in ongoing statistical programs, DOE will need, in addition to the persuasive powers of its staff, reinforced by willingness to provide financial support in some cases, the backing of an interagency body whose recommendations will be respected. DOE should consider how best to achieve this.

This chapter is organized in terms of the following general subjects: employment, employee characteristics and related data; training and education; and RD&D expenditures. The individual sources on each subject are reviewed, specific recommendations made on some of them, and then the present coverage of the subject is evaluated in general, and recommendations made for filling major gaps by new surveys or data collection systems.

Each source is more fully described in Appendix B, "Data Sources Relevant to Energy Research, Development and Demonstration Manpower." In that Appendix the sources are arranged generally by the agency or organization that publishes the data, and references in parentheses in Chapters IV and V refer to this Appendix B --- e.g. (NSF 4), (BLS 2), etc.

B. SOURCES ON EMPLOYMENT, CHARACTERISTICS AND RELATED DATA

1. Employment and Employee Characteristics

a. Introduction

Sources of data on employment in energy related activities are numerous and diverse. Some of the sources are elements of well-established systems, others are new or one-time. Both Government and private agencies produce data series. Within Government, data collectors include both statistical agencies and agencies primarily concerned with substantive program management. In some cases, data are collected from individuals, in others from employing establishments.

Historically, the interest in energy employment is a recent one, paralleling the concern for the adequacy of energy supplies, and no comprehensive consistent body of employment data has yet developed. A few series specifically measure such employment either as a part of a larger total or as a defined segment of the energy universe. In most cases, however, energy employment is likely to be included in a total which does not distinguish between energy and other employment. Accordingly, the sources cited below include many which are useful mainly to provide a base from which energy employment may be estimated. (See Appendix B for further description of sources.)

The enumerated sources are roughly organized so as to proceed from those presenting the broadest specific data on energy employment to those in which such employment may be derived or inferred from grosser totals.

In terms of the industry sectors represented by those data sources, four cover all sectors, five are entirely or predominantly private industry, two represent the Federal Government, two others primary DOE contractors, and the final four a miscellany of sectors.

b. Data Sources

i. National Sample of Scientists and Engineers (NSF 15) provides biennially data derived from sample surveys of scientists and engineers reported in the 1970 Census of Population. Such a survey, conducted by the Census Bureau and funded by NSF, was last conducted in 1976, when sample data were collected representing about 960,000 scientific and technical personnel identified in the 1970 labor force.

Data collected included labor force status (employed, unemployed, not in labor force), occupation, industry, salary, and characteristics such as age, sex, education and training, principal work activity (including R&D), and whether engaged in "important national programs." Some 115,000 reported their work was significantly related to "energy and fuel."

This source provides our most comprehensive series of data for engineers and scientists engaged in energy activities. Data collected on individuals permit maximum flexibility for employment distributions by occupation, work activity, industry, and selected personal characteristics. The historical series provides continuity from 1970, and this national sample provides perspective in relating energy employment to other activities engaging scientists and engineers.

Useful though the series is, it has serious defects. The sample includes only those in the 1970 Census with qualifications as scientists or engineers; omission of any new entrants into these occupations since the 1970 Census count is a deficiency which grows as this base date recedes in time. Plans to supplement the original 1970 sample with new entrants have not been entirely satisfactory. Only professionally qualified scientists and engineers are included in the current sample, which thus lacks representation of technicians, clerical, production, and other workers.

The present "Energy and fuel" classification of employment is not adequate when the use of the information depends upon knowing whether the worker is engaged in coal, petroleum, solar, etc.; nor is information available for regions or States. Self-reporting makes for problems of data comparability, especially for occupation-related information. Sample supplementation to correct the downward bias which results from the sample being based on labor force participation in 1970 still leaves some question of representativeness of the current survey results.

Several improvements can be made in this source which will greatly improve usefulness for energy manpower analysis. The sample should be supplemented with representation of new entrants into science and engineering occupations since the decennial census count in 1970. Such new entrants come not only from recent graduates in science and engineering, but also from other newly college trained persons, technicians, nongraduates, and other occupations. Sources of such information on new entrants include the universities and technical institutes, professional societies, sample household surveys, and employers. Experimental follow-up surveys of recent engineering and science graduates, sponsored by NSF, should be supplemented by recourse to the Current Population Survey sample which could be expanded to produce gross estimates. A useful sample extension to technicians may not be feasible until the sample selection following the 1980 census but should be explored. By adding an item to the periodic follow-up surveys, much useful information can be secured on type of energy for those engaged in these activities.

Recommendations: The National Sample should be supplemented by representation of scientists and engineers entering the labor force since 1970; similarly, technicians should be included in the sample as soon as feasible, certainly by 1980. Biennial surveys should collect information on involvement by type of energy activity.

ii. Survey of Doctoral Scientists and Engineers (NRC 2), conducted biennially by the National Research Council with Government support, samples the doctoral degree holders included in the Roster of Doctoral Scientists and Engineers. In 1975, this universe included about 278,000 doctorates, substantially all recipients of Ph.D degrees from American universities, who were professionally active in this country at that time. Information available from this source includes field and year of degree, type of employer, work activity, salary, and involvement in national programs such as energy, environmental pollution and control, national defense, etc. It is unique as a source for place of birth, race, citizenship, ethnic group, education and Government support. The 1975 survey reports 21,000 doctorates of a total of 263,000 employed, a significant part of whose professional time involved work on energy programs. A 1977 update is now in process, and new data should be available by the end of the year.

This source contributes importantly to our information on doctoral scientists and engineers, large numbers of whom are engaged in R&D and other activities relating to energy programs. Survey coverage and techniques are excellent, and the Roster of Doctoral Scientists and Engineers affords a continuing data resource for further statistical inquiry. The biennial samples permit assessment of employment on energy programs in relation to total and competitive employments for the groups covered.

Restriction of survey coverage to doctorates of course limits usefulness for estimating total or R&D employment on energy programs. Nor does this series now provide information by type of industrial employment or source of energy, which seriously limit usefulness for energy manpower analysis.

Adding type of energy involvement and improved industrial classification for the private sector items to the biennial surveys will greatly enhance the value of this source. Further, this source should be looked to as a vehicle which can be utilized either to collect supplementary energy manpower information or for specialized surveys, especially for R&D personnel.

Recommendations: DOE should propose additions to the biennial surveys to permit classification of data by type of energy activities and by Standard Industrial Classification for the private sector. DOE should encourage the use of the doctoral file to serve as a source of specialized data on doctorates involved in energy RD&D.

iii. Industrial Employment of Scientists and Engineers (NSF 11) was a one-time sample survey conducted in 1975 by the Census Bureau with NSF funding. The survey found 1,250,000 scientists, engineers, and technicians "working in private industry" and classified them in some 15 fields of science, 9 of engineering, and 5 of technicians. Data collected included numbers employed on energy and energy R&D by energy sources, work activity, highest degree held, and occupations. Some industry detail is also available.

The survey was perhaps too ambitious in attempting to secure a comprehensive distribution of scientific and technical employment in private industry by occupations, work activity and involvement in national programs. It does represent a useful first effort for measuring a difficult and complex entity. In addition to substantive information provided by the survey, experience with the techniques used will be useful in guiding future survey work. Information of this type will be needed from industry, and suggestions for obtaining it are proposed at the end of this section.

Respondents reported difficulty in extracting some of the desired information from their records, and the overall response rate was a relatively low 69 percent. Some industries and occupations were particularly subject to large sample and reporting errors.

iv. Occupational Employment in Nuclear or Nuclear Related Energy Activities (ERDA 5) conducted by the Bureau of Labor Statistics and funded by DOE, covers both the Government-Owned, Contractor-Operated (GOCO) and private establishments engaged in nuclear-related energy activities.

Separate employment data are provided by occupation groups; GOCO and private establishments; and industrial activities, such as R&D, power, weapons development, production, and design and engineering of nuclear facilities. The survey presents annual data from 1968 to 1975, and will become biennial with the 1977 collection.

Coverage of nuclear energy activities in the GOCO and private sectors is substantially complete, with 108,000 employees (90,000 in GOCO's) reported in 1975, including some 20 occupational categories. The series is unique for energy data in continuity over a 10-year period. In spite of deficiencies noted below, this source is the most complete for any energy activity.

Excluded from coverage is nuclear energy employment in government at all levels, universities, construction, uranium mining, and medical institutions. With the exception of welders with nuclear certification, skilled craftsmen are not separately reported.

Recommendation: It is proposed below that the information provided by this survey be included in more comprehensive surveys of DOE contractors.

v. Survey of Federal Intramural Performance in Energy R&D - Funds and Manpower 1973-75; Projections to 1977 and 1979 (NSF 3) was a one-time survey conducted by NSF and directed to all Federal agencies and installations, which reported intramural expenditures for energy R&D in the Federal Funds Survey XXIII. A similar collection was made for Federally Funded Research and Development Centers (FFRDC's). Employment data included scientists, engineers, and technicians working on energy R&D in 1973, 1974, 1975 with projections to 1977 and 1979. (Also see discussion of this source under R&D funding.)

This source is unusual in several respects including employment projections, detail by 11 energy program areas such as coal; nuclear fission, solar, etc., and expenditures for energy R&D. This survey reported some 8,000 scientists and engineers and 5,500 technicians employed in energy R&D in the FFRDC's, and 2,000 scientists and engineers and 700 technicians so employed in Federal intramural installations in 1975. Employment can be related to R&D funding and to type of energy. For these establishments, it is possible to compare total employment of scientific and technical staff with total R&D and energy R&D staff.

Data are limited to the agencies and installations and the FFRDC's reporting energy R&D funding in the 1975 Federal budget. Although Federal funding is substantial, direct employment is not large, and the Federal segment of energy employment is relatively small. Agencies reported difficulties with reporting concepts and definitions, and data consistency is questionable. At the time of reporting, only the 1973 data were final so that estimates were necessary for other years. The current value of the data is limited in view of the sweeping changes in energy activities since 1973.

vi. Contractor Employment and Turnover (ERDA 2) is a DOE survey conducted semi-annually covering approximately 60 GOCO facilities in which some 90,000 are employed. Data collected include employment by broad occupational category, (i.e. professional, technician, etc.) sex, and minorities. Employment separations by type, accessions, and promotions for each occupational group are provided.

This data source, taken with other contractor reports on hours worked, earnings, industrial relations, etc. provides the most detailed employment data generally available on any energy program. It is particularly useful in evaluation of contractor practice with respect to minorities employment.

The detailed labor turnover data go well beyond that which seems desirable and feasible for a broader based survey which might collect data from facilities less directly subject to Federal funding and regulation. It does represent, however, the type of information which closely controlled energy programs may be expected to supply to assure that Government funds and facilities are utilized in accord with its policies. In the event DOE actively extends the program of fair employment practices to other contractors, coverage of this report should also be extended.

Recommendation: This report should be coordinated with respect to coverage, occupational categories, etc. with DOE contractor surveys proposed below to improve comparability and minimize overlap.

vii. Occupational Employment Statistics Survey (BLS 2) is an ambitious BLS-State program designed to provide periodic employment data for some 2,000 occupations by industry and State on a 3-year rotating industry cycle beginning with 1976. Industry exclusions are agriculture, education, Federal Government, and self-employed. Data are collected on mail questionnaires tailored to principal occupations found in closely related industries. About 20 scientific and technical occupations are reported separately. The professional and technical occupations are further identified as to employment in R&D. State samples permit separate estimates for 40 participating States, and NSF supports the development of national estimates.

This source will provide useful information for those industries which are entirely or predominantly engaged in an energy activity, such as public utilities, coal mining, power generation, etc. Coverage of establishments is high, and most data are available on a State area basis. It will permit comparisons of STP with total industry employment, and provide separate R&D employment estimates for selected occupations.

For those industries less involved in energy activities, the source becomes less useful since no distinction is made between energy and non-energy activities. Type of energy involved can at present only be inferred from the nature of the industry.

This survey will be an important source of data on employment in selected STP occupations for those industries important in energy activities. It is important that DOE arrange with BLS to the end that occupations, especially STP, and establishment coverages are adequate.

Recommendation: DOE should encourage BLS to tabulate separate data on occupations and industries important to energy RD&D.

viii. Census of Population, the decennial (and expected to become quinquennial) enumeration of the Census Bureau, is a fundamental source of information on labor force status, occupation, age, education level, sex, type of employer, salaries and wages, ethnic origin, location, etc. of the population. However, the Census, as the largest statistical activity in the Nation, lacks the flexibility to provide more than general information on energy employment.

It does, however, provide background information on the occupational totals within which energy manpower is found, a framework from which more directed samples can be selected for specialized surveys. The National Sample of Scientists and Engineers is derived from the 1970 census, and we propose to develop this source further from the 1980 census as noted later in this section.

ix. Research and Development in Industry (NSF 4) has been a source of data on R&D employment and funding since 1957. The Census Bureau conducts this annual survey with NSF funding on a sample basis which covers manufacturing and selected non-manufacturing industries on an SIC company basis. Manpower data include January employment and man years worked the previous year for R&D scientists and engineers. Such data can also be related to cost of R&D performed. (Also see discussion of this source under R&D funding.)

This source is of limited usefulness as a measure of employment on energy programs. It fails to distinguish employment on energy activities although R&D funding for energy R&D is currently separately reported, and lacks occupational data. Data collection on a company basis weakens industry comparisons where multi-industry firms are involved. It does provide a standard data source of information on R&D employment by industry, and readily permits estimates of R&D expenditures per professional scientist and engineer.

x. Manpower Resources for Scientific Activities at Universities and Colleges (NSF 12), another NSF sectoral survey produces information annually in considerable occupational detail for scientists, engineers, and technicians employed in higher education. Such employees are cross classified by work activity (teaching, R&D), full-time and part-time, sex and highest degree held. Employed graduate students are separately reported. The Federally Funded Research and Development Centers (FFRDC) operated by academic institutions supply similar information on their operations.

This source covers all institutions of higher education offering degree credit courses in science or engineering. Response rates exceed

80 percent for the total, and are substantially higher for the larger institutions. The survey affords a wealth of detail on professional characteristics of academic staff, degrees held, full and part-time employment, work activities, field of employment (engineering and sciences). Similar information is available from 1965, although in less detail.

The principal deficiency is lack of information on involvement with energy programs. Nor can this be easily inferred from field of employment. The institutions report some difficulties in reporting, particularly in separating those engaged primarily in R&D and teaching.

Unless this source is adapted to provide information on employment in energy activities, it will have limited value to DOE for manpower analysis. We propose that DOE undertake to influence NSF to collect such information as another dimension for this survey. Failing to do so, the Department should consider extending its own survey program to this sector.

Recommendation: DOE should explore with NSF the feasibility of collecting information on employment on energy activities, especially RD&D, on this survey.

xi. Education and Work Activities of Federal Scientific and Technical Personnel (NSF 10) is a source of data collected by the Civil Service Commission (CSC) and analyzed and published by NSF. Annual data reported include employment in the Federal Government by occupational series, grade, work activity, and agency for scientists, engineers, and technician support personnel. Approximately 10 percent (161,000 in October 1973) of the nation's scientists and engineers are Federal employees.

This source provides considerable information on Federal personnel, including occupational fields, work activities, and level of education (when related to other data from the Commission's Central Personnel Data File (CPDF). A 1976 release is now in preparation.

Deficiencies for energy employment purposes are similar to most of the other NSF sector studies, i.e. failure to distinguish those engaged in such activities. Furthermore, data are published late, frequently several years after the reference data. Most recent release (NSF 76-308) in May 1976 reported employment as of October 1973.

This source can be improved for energy manpower analysis by (1) identifying employees engaged in energy activities, (2) conversion of CSC occupational series into selected relevant energy occupations, and (3) speeding up the release of the data.

Recommendations: Encourage CSC to identify Federal personnel engaged in energy activities by technology; DOE to convert CSC series into appropriate occupations important in energy; and NSF to publish more promptly.

xii. Other NSF Sector Surveys of Employment of Scientists and Engineers are conducted from time to time to provide data on such minor employment categories as State and local governments (NSF 5) and miscellaneous non-profit organizations, as research institutes, hospitals, museums, (NSF 8) etc. These sources serve to round out the employment universe for NSF, and provide limited occupational and type-of-work information. State and local governments employ as many as 9 percent of all scientists and engineers, but fewer than 2 percent of those in R&D. Coverage is occasional and spotty in occupational categories and usefulness for energy manpower quite limited. (See also discussion of these sources under R&D funding.)

Until such time as DOE develops an improved data system, it should look to NSF to provide R&D manpower information for this sector, especially the State and local governments and non-profit institutions. As it is able, DOE should seek to influence such data collection to secure occupations important to energy R&D and type of energy involved.

Recommendation: DOE should encourage NSF to collect RD&D employment data from the several minor sectors, including further detail on occupations and energy technologies.

xiii. Employment, Hours, and Earnings (BLS 5), the monthly employment series of the BLS, provides industry information peripherally useful for selected industries. Although no occupational detail is provided, the employment information on total and production worker employment, hours of work and earnings is useful as a current measure for energy intensive industries (coal mining, petroleum production and refining, electric and gas utilities, etc.) and also to measure overall employment trends.

xiv. Regulatory Agency Reports are sometimes a source of employment information. Federal Government agencies, such as the Interstate Commerce Commission (ICC), the Federal Power Commission, and Federal Communications Commission, frequently require certain employment information in connection with reports filed with them by regulated companies. Such reports typically call for the average number of employees with little or no occupational detail or R&D involvement. An example is the annual report of interstate petroleum pipeline companies which report annually to the ICC on average numbers employed by occupational groups, including a category "professional and subprofessional employees." (ICC 1) Such data are now of marginal value for energy employment uses, but do afford a measure of employment for the Federally regulated utilities. However, the recent transfer of Federal responsibilities relating to electric power, gas and interstate pipelines to DOE affords the opportunity to review reports on employment now required from the standpoint of making them most useful to DOE.

These reports can be improved by incorporating standard occupational specifications for employment reporting and by the summarization and release of the data when available.

Recommendations: DOE should review the reports required of regulated companies in the electric power, gas, and pipeline industries calling for employment with the view of standardizing occupational and other report specifications, tabulating the data, and publication for wider use.

xv. Inventory of Energy Research and Development (ORNL 1) a survey of the Oak Ridge National Laboratory funded by DOE and NSF, collects information from R&D performers on type of organization, industry (SIC), employment, expenditures, energy sources, and related information. R&D projects funded at $5,000 or more per year are reported individually by funding and employment of full-time equivalent scientists, engineers, and graduate students assigned to the project. (See also description of this source under R&D Expenditures.)

The Inventory lacks occupational detail and the employment reporting specifications are imprecise. The Laboratory claims coverage of some 80-85 percent of all R&D projects in 1973. The survey may be most useful as a point of departure for developing a Directory of R&D establishments.

xvi. Other Miscellaneous Series - There are several other data sources which provide some related employment data on selected occupations or activities from time to time. These include the estimates produced by professional societies, trade associations, and research institutes. Those discussed below are representative, but by no means complete, examples of such information sources.

Professional societies frequently compile data on types of employment, income, and education of members of the profession. Generally, the data are restricted to members of the society, although occasionally some nonmembers will be included. Such information may be related to periodic studies of the status of a particular profession. The data are usually collected from individuals with some supplemental employer reporting. Examples of such programs include the American Chemical Society, the American Institute of Physics, the American Society of Civil Engineers, the American Nuclear Society, and the Engineering Manpower Commission.

Trade Associations from time to time may collect data from their industry members and from educational institutions to determine current employment and prospective trained manpower additions. Such data are limited in scope and coverage, but useful for specific industry segments. Examples include the Air Conditioning and Refrigeration Instit (ARI) with periodic estimates of employment in selected occupations drawn from Government and membership surveys.

Research institutes are a source of information, generally for specific groups on an occasional basis. An exception is the Battelle Institute annual survey of salaries of R&D scientists and engineers (BATL 1), funded by DOE; although not an employment series, it provides related information and might provide an alternative data source if tailored to energy R&D specifications. Another example is the study of the Center for Advanced Computation of the University of Illinois,* which provides STP employment projections for industries important in energy production and utilization based upon present

* Hugh Folk, et al., Scientific and Technical Personnel in Energy-Related Activities: Current Status and Future Requirements, Center for Advanced Computation, University of Illinois, Champaign-Urbana, Ill., July 1, 1977

establishment patterns of employment and taking into account future physical production levels.

The foregoing sources have dealt with the principal data sources for current and past employment. A subsequent section reviews sources of data on projections and forecasts related to energy employment.

c. Summary Evaluation of Existing Employment and Characteristics Data

The search of data sources on employment and characteristics of workers engaged in energy RD&D reveals the spotty character of current data which have mainly been developed for other purposes. Sources tailored to energy employment uses are few, but several might be modified enough to be useful with varying degrees of difficulty.

Frequently, the addition of type of energy involved to the data source immeasurably enhances the value for energy manpower analysis. For example, such additions to the National Sample (NSF 15) and the Doctoral Degree Holders survey (NRC 2) would provide measures directly applicable to the universe of energy employment. Several other sources would be improved by similar modification such as the NSF university and college survey (NSF 6), the CSC file of Federal personnel (NSF 10), and the miscellaneous NSF sector surveys (NSF 5 and 8).

Expansion of existing sources to additional coverage of occupations important in energy R&D would be useful to evaluate the extent of specific occupational involvement in energy. Such recommendations are proposed for the National Sample and the reporting systems of the regulated industries, newly the responsibility of DOE. Utilization of a standard list of R&D occupations, where occupational data are collected, and convertibility to the Standard Occupational Classification (SOC) readily permit comparisons between data sources.

d. Further Initiatives for Improvement and Development of Data Sources

1. Development of a Base Line Measure of Energy RD&D Manpower - High priority should be assigned to developing an energy RD&D employment base line measure. Initially, coverage can be restricted to scientific and technical occupations at the professional and semi-professional levels,

such as scientists, engineers and technicians. At a later date, experience may indicate that coverage should be extended to selected crafts important to successful energy activities.

The base line should include professional and personal characteristics data of the employed target population such as field of energy, occupation, type of work, type of employer, and highest degree. Lower priority might be assigned to such data as sex, age, field of study, and location of work or residence. While the base line data serve to answer a great many of the questions which arise, it also will serve as the sampling frame for developing more specific and sophisticated data.

The establishment of an energy employment base line calls for identification of either all the employers of such workers or the workers themselves. In the absence of any appropriate standard employer report from which such a base line can be abstracted, the most feasible approach seems to be to the workers. A further advantage of this approach should also be greater access to worker characteristics information which employer reporting systems find difficult to report.

The employment base line could best be developed as an adjunct to a Population Census. As noted, the energy manpower component of the labor force is relatively small, and the mammoth mechanism of a census should not be expected to subject the entire population to the specialized data items required for the proposed measure. A census, however, could serve as a wide-mesh screen to provide a smaller group from which the base line might be developed.

Both the 1960 and 1970 Population Censuses identified selected scientific and technical occupational groups which became the subject of more comprehensive surveys in 1962 and 1972 under auspices of the National Science Foundation. A similar survey is now proposed for 1982, following the 1980 decennial census. This timing provides an unparalleled opportunity for the cooperative development of the de[illegible] base line.

We propose that [illegible] work with NSF and the Census Bureau to identify employees working in RD&D energy activities in scientific and technical occupations found in the 1980 Census. This might take the form of a 1982

95

post-censal sample survey of the selected Census occupational groups, in which employment in energy activities is likely to be found. Several options by which desirable detail, such as energy category, may also be collected are possible. They include additional detail in the NSF sponsored survey, either as an integral part or as a supplement for energy workers; a third stage sub-sample of the 1982 survey directed to energy employees; or a 1982 separate sample survey based on the 1980 occupational groups.

Whichever option is selected, the continuing interest and access to the sample cases on the part of DOE should be established early. In the event Census maintains control of the energy base line file, there must be adequate opportunity to exploit it to meet DOE information needs.

The year 1985 will mark the first mid-decade census. At present, the exact nature of this census is unclear, but it is expected to be less detailed and place greater reliance on sampling than the regular decennial census. It should still serve, however, to update the energy RD&D employment base line at 5-year intervals through use of techniques similar to those proposed to follow the 1980 Census.

ii. <u>Development of a Directory of Establishments Conducting Energy RD&D</u> - Another basic tool for the manpower information program is a directory of industrial and other establishments performing energy RD&D. In a sense, it provides a data file in this area similar to the employee base line proposed in the preceding section. The directory should include such information as name & location, principal activities, energy RD&D activities, employment total, industrial classification, and RD&D expenditures. Useful as an inventory of energy RD&D facilities for appraisal of progress toward goals, the directory provides also a sampling frame for periodic and special surveys with respect to manpower.

The directory should be compiled from diverse sources, including DOE contractors, NSF survey respondents engaged in energy RD&D, trade associations and publications, industrial research directories, and the like. It should include appropriate respondents identified in other Government surveys, such as R&D surveys of the Census Bureau and employment surveys of the BLS, and the R&D inventory of ORNL.

Maintenance of such a directory should probably be a responsibility of DOE which is in the best position to assure the inclusion of DOE contractors. But whether maintained in DOE or elsewhere, access to the directory for DOE survey purposes should be guaranteed. Coverage should be broad, including industrial, government, and academic establishments, but subject to a small size cut-off such as annual RD&D expenditures of $200 - 300,000 per annum.

iii. Internal DOE and Contractor Reports The Department of Energy constitutes a unique organization structure for the conduct of Federal programs. The several National Laboratories (e.g., Argonne, Oak Ridge, Los Alamos, etc.) established under the Atomic Energy Commission, which have expanded to include many different types of operations covering several sources of energy and many variations in energy technologies, are one key set of establishments. Some parts of this system of laboratories are operated by industrial concerns, some by universities or university consortia, and by non-profit organizations. Another set of establishments are the Energy Research Centers (e.g., Bartlesville, Laramie, Pittsburgh), operated by Federal employees, which were formerly under the aegis of the Office of Coal Research in the Department of Interior. There are also separate laboratories and facilities, some operated under contract with non-federal organizations and some by intramural arrangements. These include Bettis Atomic Power Laboratory, Ames Laboratory, Stanford Linear Accelerator Center, Savannah River Ecology Laboratory, Solar Energy Research Institute, New York Health and Safety Laboratory and many more facilities.

Thus, operating under the new seal of the Department of Energy is a wide assortment of organizations, facilities, plants, sites and offices which carry out the many programs of the Department. The operations, management, and conduct of programs are as varied as the separate facilities. The manpower engaged in these activities is substantial.

Discussion of manpower data needs with DOE officials brought to light several piecemeal information systems or data collections which exist in the several organizations now organized under the Department of Energy. They include the budget and reporting system (under which expenditures for all ERDA programs were categorized, including R&D programs -- (See Appendix A); the proposed collections to be undertaken under the Uniform Contractor Reporting Guidelines (UCRG); the "institutional plans" submitted in response to the call of the Assistant Administrator for Field Operations; Program Approval Documents (PAD's); the Contractor Statistics Program covering GOCO's; and the detailed data submitted in connection with the annual budget cycle (to Head of agency, OMB and the Congress). These examples pertain to the former ERDA, but similar sources exist for several of the other agencies now in DOE, e.g., FEA, parts of ICC, etc. However, together these information systems do <u>not</u> represent a comprehensive or integrated source of information on spending and manpower involved in the various programs conducted by the units now constituting DOE. Rather, they are in the nature of limited operations reports serving some of the specialized needs of specific programs and managers.

As program managers perceived new manpower data needs, they have developed reports specific to their immediate purposes, but of limited value for other purposes. In some cases, it may be possible that revisions of such existing reports will meet the specifications of the more comprehensive CEMIS. In other cases, new reporting will probably be necessary. In any event, the new reports should be related and consistent with present reports as much as possible to reduce burdens.

The manpower with which DOE is most directly concerned is that which is employed by Federal establishments and the closely controlled GOCO's which are funded by the Federal Government. Next is the manpower engaged on work in private establishments, but funded by DOE or other Federal agency contracts and grants. For these two segments, we propose a data collection program to cover STP employment and RD&D expenditures as follows:

1. <u>STP Employment in DOE and GOCO's</u>

Coverage: Federal personnel in DOE units, contractor personnel in Government-owned installations whether or not engaged in RD&D.

Content: Employment by STP occupation, work activity (RD&D stage or other), energy technology or other, highest degrees held, sex, race or ethnic identification;

98

and RD&D costs by energy technology and work activity (RD&D stage).

Frequency: Annual

2. Other STP Employment Funded by DOE or by Other Federal Agencies in Energy RD&D

Coverage: Other employment funded by DOE contracts and grants, and other Federal direct, contract, and grant employment in energy RD&D.

Content: Employment by STP occupations, work activity (RD&D stage), energy technology; and energy RD&D costs from Federal sources by energy technology and work activity (RD&D stage).

Frequency: Annual

The establishments covered by the above reports can be readily identified through accounting and fiscal controls as well as from the proposed Directory source. These annual reports should cover all such employing units, and be geared, if possible, to existing operations reports in the interest of data consistency and minimizing report burden. DOE should arrange with the appropriate Federal agencies for data collections from the non-DOE funded programs.

The reports in these segments are closely related to DOE operations, and should be an important responsibility of that agency. It is recognized that other agencies -- notably NSF -- also have important interests in such data, and cooperation between them is a necessity. The relation to DOE operations is likely to provide stronger incentives for effective data collection than the more general economic data interest of NSF. However, the possibility of NSF collecting manpower and RD&D costs in the detail proposed from the RD&D performers other than DOE and GOCO's should be explored.

iv. Other RD&D Manpower and Expenditures Reports - The reports proposed above will cover approximately one-half of the RD&D annual costs and STP manpower involved in energy activities. They cover that portion in which Federal interests are greatest. The other segment -- that funded by private sources -- is less subject to DOE influence and the more difficult from the standpoint of data collection.

A series of reports is proposed to provide information on employment

98

and expenditures for the energy RD&D programs funded from all other sources, including private industry, universities and non-profit organizations, State and local governments, etc. The Directory of establishments proposed earlier will provide a universe from which samples may be chosen for annual surveys of employment and RD&D expenditures levels by energy categories as follows:

3. Other STP Employment in Energy RD&D Funded by Non-Federal Sources*

Coverage: Other workers in private industry, universities, non-profit institutions, State and local governments, etc. funded from other than Federal sources.

Content: Employment by STP occupations, work activity (RD&D stage), energy technology; and amount and sources of RD&D funding by energy technology and work activity.

Frequency: Annual.

It was not possible to make a thorough review of all existing reporting to determine the extent to which the proposed CEMIS would meet specialized operations requirements, or conversely, the extent to which specialized reports would satisfy the broader requirements of the CEMIS. Nor would such a review be timely, in view of uncertainties in organization and program evident in DOE as this report is being completed. What started as an assignment related to ERDA's responsibilities for energy RD&D has been caught up in the press of new and enlarged responsibilities of DOE.

The CEMIS represents methods by which STP manpower supply and requirements may be evaluated within the framework of the broad national labor force. But it also represents a system which should meet many of the special-ized needs and permit adaptations for meeting other requirements of the operations managers. New operations reports, as they develop, should be consistent with the CEMIS, that is, follow similar definitions and specifications.

* This survey may exclude certain coverage segments to the extent that similar information becomes available from other sources, such as the NSF sector surveys. The more comprehensive specifications here assure that the three surveys together will cover the entire range of STP employment in energy RD&D.

2. Earnings

a. Introduction

As we have noted, information on the comparative pay of energy R&D practitioners can be used as:

1) indicators of change in the balance of manpower supply and demand in individual occupations and specific fields of R&D activity;
2) references for personnel management to compare their establishment's experience with that of a norm or as a basis for their establishment's pay policy; and
3) a basis for revealing adherence to public policies such as pay equity for minorities and for women.

The responses of pay scales to the forces of supply and demand do not always coincide with those called for by classical theory, but the effects of these forces can nevertheless be detected once expectations of responses are modified to coincide with the realities of actual labor market operation.

Characteristically, especially in recent years, compensation indicators shift primarily in the upward direction to take account of inflation and to reflect increases in demand for a skill category of employees in relation to their supply. Because of institutional restraints and rigidities, pay scales for experienced workers generally do not decline where manpower demand contracts or supply expands, although entrance rates may be more responsive to the market; but where those conditions continue over any sustained period, there usually is a slowdown in the rate of pay increases for experienced workers in the affected occupations as compared with others where a tighter labor market exists. In reflecting supply/demand imbalances, the indicators would be expected to show divergencies in the rates of pay increase rather than actual declines.

Evidence of an upward divergence in comparative pay of specific categories of scientists and engineers would obviously be an important consideration for R&D administrators contemplating any significant program expansion involving additional demand for those scientists and engineers. The evidence of divergence would be a signal that the manpower supply may be inadequate and has to be critically examined to determine the viability of the prospective program unless additional supply can be assured. The evidence of rising manpower demand in allied R&D fields would also require consideration, because a spillover of this demand could be expected in occupations and activities where some interchangeability is possible. Policy officials with broader concerns would also have to consider whether pressures for maintaining pay comparability would affect related occupations having similar professional status.

Comparative pay data would have additional usefulness in situations where the Government directly employs or indirectly supports a large proportion of certain types of scientists and engineers, as it does in the nuclear energy field. These data would provide suggestive indicators of managerial ability to establish the delicate level of pay correspondence or equivalency among different hiring units and among the Government facilities, in general and all others. Even a divergence of pay levels below those of the comparative standard (assuming no change in other significant factors such as fringe benefits) could be a warning to management that pay practices might be undermining a program's longer term ability to recruit and keep quality personnel, while upward divergencies suggest the possibility that pay rates are excessive. Where the Government is a very substantial employer of a given specialty, and its pay scales effectively established the market scale, R&D policy officials would have to consider whether lower pay scales might be a disincentive to entrants into specialized training and would reduce the ultimate manpower pool available for employment in the occupation. Conversely, significantly higher pay scales should raise the consideration not only of disruptive inflationary pressures on allied specialties, but of prospects of an oversupply of available manpower at a future date. Pay is of course not the only determinant of manpower supply, but it is one important determinant that must be considered with other factors.

The usefulness of pay data therefore depends heavily on their comparability. This involves internal comparability of data series over time as well as precision of identifiable data components in any measure that is to be compared with other pay measures. Reasonably precise and uniform occupational identifications are required for meaningful comparisons, and, ideally, the data should identify such factors as education, experience, level of job responsibility, supervisory status, and similar factors which determine pay scale differences in the labor market. Since comparisons figure so heavily in the usefulness of pay data, statistical validity of the data is critical, involving such factors as adequacy and representativeness of the sample drawn, adequacy of survey response, and statistical biases in the framing of questions or the conduct of the survey.

b. Data Sources

The principal data sources on compensation are these:

i. <u>National Survey of Compensation Paid to Scientists and Engineers Engaged in R&D Activites</u> (BATL 1). These are conducted for ERDA by Battelle Columbus Laboratories. The latest annual survey, 1976, is the 9th conducted by Battelle; a predecessor survey conducted by the Los Alamos Laboratories of AEC extends back to the late 1940's.

Monthly salary data are given for: supervisory and nonsupervisory scientists and engineers by field and level of degree, age, years since bachelor's degree, type of institution (nonprofit research, educational, contract research center, Federal establishment, private industry), and occupation classified under eight branches of engineers, or as scientists in physics, chemistry, atmosphere/earth/marine/space scientists, agricultural/biological scientists, economists, mathematicians/statisticians and computer scientists. Data also are given on ratios of technicians to scientists by type of establishment and proportions of scientists and engineers without degrees. Starting salaries are shown by level and field of degree. A key element in the survey approach to compensation differentiation is that of identifying "age-wage" data on both chronological age and years since receipt of degree.

An attempt is made to increase the accuracy of year-to-year comparisons by identifying separately the measures obtained from identical respondents over a 5 year period. However, there is a low level of response in the total survey to the questionnaires (only 304 of 802 contacted establishments responded) and there has been a steady attrition in the identical sample. The low level of response to the survey may bias the accuracy of the reported salary levels. Although trend comparisons over time would have greater validity, some bias is also likely in this as a result of attrition in the identical sample.

The measures appear to have greatest validity in showing relative pay differentials (rather than levels) based on degree level, years of experience since receipt of degree, supervisory status, etc., and also in showing comparative trends.

The information collected by Battelle is derived from employer reports on the establishment and from employee reports, submitted through the employer, on personal characteristics and functions. In practice, the employer completes many of the individual report forms from personnel records. The low state of employer cooperation in this survey may be related to the reporting burden that employers appear to have assumed for supplying information on each of their employees. Inasmuch as this survey aims at being the broadest-based and most authoritative measure of compensation for scientists and engineers in R&D work, special efforts are plainly called for to shore up the response rates. No special remedy appears obvious, but a review and possible rectification of the survey procedures, and some influential promotion activity, could produce the desired result.

Recommendation: DOE should formally review the administration and procedures of the Battelle survey, or, in cooperation with other agencies concerned with earnings data on technical manpower, convene a panel to conduct such a review, with the aim of improving the accuracy and validity of this important data source.

ii. Comparison of Compensation Paid to Scientists and Engineers in Research and Development, 1976 Data (ERDA 9) Prepared by Oak Ridge Operations Office for ERDA.

This study involves statistical analysis involving the general survey data source (BATL 1) and a parallel special survey of ERDA laboratories, part of which is represented in the broader survey. It represents a systematic comparison of compensation paid to scientists and engineers in 18 ERDA laboratories and those covered by Battelle's National Survey. (Seven of these laboratories are already represented in the sample for the national survey.) The data content and survey approach is essentially the same as BATL 1. Comparisons are made by type of establishment, educational level (degree), management status, age, years since receipt of degree, field of highest degree, and rate of compensation increase over previous years. This comparison is an example of a practical use of two related bodies of statistics, aimed at determining patterns of difference in compensation between Federal energy R&D establishments and the general universe (public and private, energy and nonenergy) of R&D establishments. The validity of the comparisons, whose limits are described in detail, is severely circumscribed by some lack of occupational detail and consequent unrevealed differences in the composition of the compared workers, and by other differences, but the survey compensates for this by the pragmatic approach of identifying "age-wage" and other factors which can be more practically reported and which seem to be fair determinants of pay. The survey and its analytical accompaniment is accepted as the best available measure of comparative pay practices for the universes compared and therefore serves as a practical reference tool for personnel and compensation policy. The practical use of such a comparison, affecting as it does individual's compensation, Government establishments' payroll costs and labor market pay scales, points up the need for reinforcing the validity of the compensation data for the universe on which the comparison relies (that is the Battelle Survey for all R&D work). The survey of DOE laboratories is conducted annually, relying on reports from 18 of the approximately 60 GOCO facilities.

Recommendation: DOE should examine the feasibility of adding occupational detail to the 18-laboratory portion of the salary survey. Also, the survey should be extended occasionally to the remainder of the GOCO universe and to other DOE contractors to obtain comparable data on all DOE-supported RD&D personnel. The extension of the survey should assist DOE to assess comparative pay practices and effects of labor market developments in all of the facilities in which it has a direct concern.

iii. Report of Contractor Hours and Earnings. (ERDA 1) This is based on semiannual reports to ERDA of some 60 Government-Owned, Contractor-Operated (GOCO) facilities. It includes, for all establisments, and for specified categories of establishments, employment, manhours worked and payroll for scientists, engineers, professionals, and other occupational categories of approximately 90,000 employees in GOCO's. About 40 percent of total employment is scientific and technical. Reports are semiannual for consistent reference dates -- weeks including the 12th of March and September. Occupational detail is meager and there is no separate identification of R&D activity. Extensive beefing up of occupational detail appears to be feasible and emphatically is desirable, both for employment information and for increasing the utility of the salary information.

Recommendation: DOE should expand the occupational detail reported in the Contractor Hours and Earnings Survey to make the information more useful for manpower analysis. Occupational detail should be consistent with that proposed elsewhere in this report for intramural and contractor reporting.

iv. National Survey of Professional, Administrative, Technical and Clerical Pay Survey "PATC" (BLS 1). This is conducted annually by the Bureau of Labor Statistics to show average salaries and rates of salary change in rigorously described occupations in private industries. The measures are used as a basis for making Federal Government pay rates comparable to those of private industry for corresponding levels of responsibility. The survey covers 20 occupations and 82 work levels. Those relevant to science and engineering include chemist and engineer (8 levels of each are surveyed -- 2 entry and 6 work levels), and engineering technicians (5 levels). The data for individual occupations and work levels are used both by the Federal Government and private employers to assess the comparability of their pay structures with that of private industry as a whole, but actual adjustments in the Federal pay structure have usually been applied across the board to all occupations in the classified service. The PATC measures are the basis for the adjustments ordered by the President's Pay Agent (the Directors of the Civil Service Commission and Office of Management and Budget acting in concert). For a few occupations in the Federal Government, higher entry pay than the regular Federal scale has been permitted, at least in part on the evidence of the PATC findings.

This survey is perhaps the most authoritative and rigorously controlled measure of pay practices (both pay levels and rates of change at different stages of responsibility for precisely defined occupations) yet it is subject to the technical and political criticism that any acknowledged evidentiary basis for billion dollar decisions is likely to receive. The principal technical criticism is that small establishments are excluded from the survey, but any upward bias this produces is less likely to be relevant to professional occupations than to other occupations where differences in "primary" and "secondary" labor market pay practices are known to be important factors.*

In addition, state and local governments and universities are excluded from the survey, but the effect of this exclusion on the pay averages is not known. Although the survey is costly, its precision and the likelihood that it provides the most accurate reflection of pay scales as a response to supply and demand influences (as well as institutional and other influences) suggests the survey would be the appropriate statistical vehicle to serve DOE needs as well as those of the Classified Civil Service System that it now serves. Authoritative reference base data on pay scales in private industry will be essential if substantial expansion in Federally sponsored energy R&D is contemplated.

Recommendation: DOE should explore with BLS the enlargement of PATC survey coverage to include other scientific and technical occupations and R&D functions. BLS should also be urged to continue the examination of the effect of exclusion of small firms from the measure and to examine the effect of excluding governments and universities.

* Of the extensive literature on differences in pay and employment practices between primary and secondary labor markets, the following work is illustrative and explanatory of the relatively uniform and stable conditions applying to the usual employment establishments of professionals such as scientists and engineers, and the more variable conditions applicable to employment of workers such as laborers and operatives: Peter B. Doeringer and Michael J. Piore, Internal Labor Markets and Manpower Analysis, Lexington, Mass: D.C. Heath and Co., 1971.

v. National Sample of Scientists and Engineers (NSF 15) In addition to the employment characteristics (described in the previous section), salary data are shown, but for aggregates and not for the detailed work categories which are cross-tabulated with other components. Salary data for detailed work and personal characteristics categories are collected from the individuals surveyed, but it is not known if cross-tabulations for salary and these other components are feasible or would have statistical validity.

Recommendation: - The potential for tabulating greater salary detail should be explored by DOE with the NSF sponsors of the National Sample Survey.

vi. Income of Families and Persons - Census Bureau P-60 Series (CENS 3) The income data are based on an annual survey conducted through the Current Population Survey (on which the monthly report on the labor force is based). Annual income is reported by broad industry and occupational categories accounting for the longest employment during the calendar year. Originally, the occupational detail was no finer than that of the broadest categories (e.g., "professional, technical and kindred personnel"), but with the expansion and refinement of the CPS sample, data have for the past few years been shown for categories such as "engineers" and "scientists and mathematicians". This information could be useful in assessing the comparative economic status for these professions as a whole but it would be only peripherally relevant to the concerns regarding scientists and engineers in energy R&D. Continued expansion and refinement of the CPS sample, which has been under consideration, should make it possible for some more detailed occupational identifications and allow the broad comparisons with other occupations that this general population survey permits, but the practical prospect of securing specific energy R&D identification through foreseeable expansion of a current population survey is remote. Expansion of salary detail on energy R&D practitioners is plainly more feasible in surveys aimed at establishments or individuals previously identified as conducting R&D activities than in a broad-based, enumerator-conducted household survey.

vii. The Endicott Report: Trends in Employment of College and University Graduates in Business and Industry (also known as the Northwestern University Survey (NWU 1) Prepared by Northwestern University's Placement Center.

Primarily designed as a self checking forecast of labor market prospects of graduates, this survey reports company intentions and efforts on the hiring of graduates during the next year by offered starting salary, with a follow-up report on the extent to which these efforts were successful. Data are given on number to be hired (and actually hired in the subsequent report) by sex, salary level and degree level for occupational groups including engineering, chemistry, mathematics/statistics, and 6 nontechnical fields. Data include distributions and averages of starting salaries predicted and actually offered by degree level and occupation. The sample is small and not representative of small establishments, universities and government, but nevertheless has proved to be a sensitive indicator of tightness and looseness in the labor markets of broad occupational categories. (Review of the survey results for chemists shows a persistent understatement of predicted starting salaries compared with actual starting salaries. The amount of understatement is, however, variable, and taken together with the reported differences between predicted and actual hirings, appears to reflect variable conditions of supply and demand.)

viii. Survey of Doctoral Scientists and Engineers. (NRC 2) Conducted biennially by the National Research Council primarily for the National Science Foundation, shows data on an extensive range of characteristics for doctoral scientists and engineers. These comprise about 280,000 out of a universe of roughly 1.8 million scientists and engineers, the difference representing those without Ph.D. degrees. The data include median annual salaries according to a variety of personal and professional characteristics. Data are also shown on employment status, utilization by field of specialization and personal and professional characteristics including changes over time. Some special uses are suggested by the variety of data, such as analysis of the extent of the gap in salaries between doctoral women and men scientists and engineers with comparable characteristics and the degree to which this gap may have been narrowed or widened over time. This survey, together with the National Sample of Scientists and Engineers (NSF 15) and the New Entrants to Science and Engineering (NSF 17) comprise the National Science Foundation's Manpower Characteristics System (MCS). The particular value of this system is that the information is collected from individuals rather than employers and hence can include characteristics not always known to employers.

ix. Federal Employment of Scientific and Technical Personnel (NSF 10). Based on tabulations of the U.S. Civil Service Commission (CSC), and initially collected through an annual occupational survey of Federal agencies, the data are now derived from the regularly updated Central Personnel Data File. Analysis and publication are conducted in cooperation with the National Science Foundation. Coverage is of Federally employed scientists, engineers, technicians and health personnel. Median salaries can be tabulated according to an extensive range of characteristics, such as occupation (by CSC series), highest degree, field of highest degree, age, function (research identified separately from development), sex, minority status, grade, agency, location by state and some area identification, and supervisory or management status (this item introduced in 1977).

x. College Placement Council Annual Survey of Job Offers to College Graduates (CPC 1). This source reports on number of jobs and starting salaries offered by industry to graduates by field and degree level. The fields include the major engineering specialties, agricultural science, math, computer science, biological science, physics and earth sciences, plus business, accounting, humanities and social science. The reports are based on offers received by graduates, which may be multiple for the individual and may also reflect duplicate offers made by firms knowing that some of their offers will be rejected. The data reflect on-campus recruiting efforts mainly by large firms. Notwithstanding duplication in numbers of job offers and exclusion of a large part of the employer universe, the offering salaries may be indicative of large employers' perceptions of the supply/demand balance, and the trends from year to year may reflect changing market conditions.

xi. Professional Societies. A number of professional societies collect and publish compensation data. Among the data sources are:

1) American Institute of Physics

Manpower Studies in Physics. This series of studies includes:

a) AIP 1973 Register covers 50,000 physicists, shows salaries by various characteristics -- major fields, highest degree, etc.

b) Some of the Society's other manpower reports on subspecialties and graduates in physics include compensation data. The surveys and analyses are generally of high quality for the group covered. Comparability with other salary data is not known.

(2) American Nuclear Society, Nuclear Employment Outlook (1975) (ANS 1)

This is an annual survey of employers to determine manpower demand for both experienced professionals and new graduates and shows salary data for current and previous years.

(3) American Society of Civil Engineers

a) Survey of Profession (latest, 1976) Conducted quadriennially of members and includes salaries and fringe benefits.

b) Salary Survey, (latest, 1975) Conducted biennially since 1951, latest survey covers 1,000 employers of 53,000 civil engineers.

These surveys do not have particularized relevance to energy R&D manpower, but provide background levels and trends on occupations with comparable status.

(4) American Chemical Society

a) Professionals in Chemistry 1975

Includes (along with characteristics and employment data) pay data by level of degree and experience. It appears to be a carefully conducted survey with high quality analysis. The pay data (including over-the-year rates of change) are compared with those from other sources ("Battelle" and "PATC") and appear to correspond rather closely. This comprehensive status report is supplemented annually by:

b) Report of Chemists' Salaries and Employment Status, 1977. Contains 95 detailed salary and income tables (separate for chemists and chemical engineers) including salaries by sex, employer, work function, specialty, geographic region, industrial or academic employment (by functions, specialty, etc.) and by number of subordinates. There are series on starting salaries by degree level (some of the data extending back, on an annual basis, to 1960) and on "comprehensive" salaries.

(5) Salary data are also provided by a number of other professional societies, by professional newspapers and magazines, and by educational and other institutions. Among these are:

American Institute of Biological Sciences
American Mathematical Society
Engineering Manpower Commission (EMC 1)
(Extensive regular publications on experienced engineers' salaries, starting salaries, salaries of technicians and technologists)
National Society of Professional Engineers

xii. Salaries of Scientists, Engineers, and Technicians (SMC 1) This summary of a broad variety of salary surveys was prepared by the Scientific Manpower Commission. The publication provides a thorough coverage of scientist and engineer salary sources and some comparative analysis of the data findings. Unfortunately, there is no analysis of differences in quality of data or data coverage of the manifestly disparate data series.

c. Summary Evaluation of Existing Earnings Data Sources

In areas of manpower information other than earnings, it is often necessary to convert or abstract tangentially relevant data from sources developed with little concern for R&D manpower, and to impute findings for other groups to those of R&D manpower. Fortunately, there are earnings data sources specifically focused on R&D manpower, or on the closely allied universe of scientists and engineers. None of them, however, are so ideally focused or comprehensive as to provide data specifically on that fraction of the universe of scientists and engineers engaged in energy R&D. The lack of precise relevancy is not, however, the major problem in obtaining accurate data that can be legitimately used in a manpower information system for the purposes described previously in comparative pay analysis.

Judged against other criteria determining usefulness, the presently available information sources on earnings of energy RD&D personnel comprise a mixed bag. Data are fairly plentiful, but the levels of occupational specificity vary widely. The pay data that are collected in surveys primarily intended to measure employment status (such as "The National Sample" data, NSF 15) are published as generalized averages, although they are collected from individual respondents on the basis of specific occupational detail and possibly could have been coded and published in greater detail. Data compiled by various professional societies on their members cover disparate fragments of the scientist and engineer universe, but provide the most current and most detailed glimpses available on relative pay and pay trends for certain occupational categories. The surveys designed specifically for pay comparisons, such as "Battelle" (BATL 1) and the ERDA Compensation Surveys (ERDA 9), are the most comprehensive for the relevant universe and best meet the standards of comparability that determine their utility, but questions of statistical validity are associated with the broader measure because of a low survey response rate. One of the most precise sources of data on pay according to level of responsibility is the Bureau of Labor Statistics "PATC" survey (BLS 1) which includes chemists, engineers and engineering technicians, along with 17 other non-scientist/engineer occupations. Data from this survey are used to adjust Federal pay scales to levels of private industry equivalency not only for Federal chemists and engineers where direct comparison can be made with private industry pay scales, but for other professional occupations whose pay scales are imputed to those of chemists and engineers.

Because average earnings generally progress with experience, especially in professional occupations, it is important to have the data by age or years of experience: an occupation with a higher average age will have a higher average earnings for this reason alone. Also, entrance earnings, or those for young workers, are likely to be more responsive to the labor market than those for older workers, and so are useful for analysis. Only a few sources give these kinds of data.

The Battelle National Survey of Compensation (BATL 1) is conceptually adequate in coverage, although further identification of the energy area would be useful and seems to be feasible. The principal difficulty with this data source is that the problem of statistical validity has assumed serious proportions with a decline in industry cooperation and a consequent serious falling off in response rates. The problem may not be easily solved, but the importance of the earnings information produced by this survey and the close conceptual fit of its universe of coverage certainly warrants a major review of the survey's performance and a major effort to improve its statistical validity. The ERDA Survey of Compensation (ERDA 9), part of which is included in the Battelle survey, does not suffer from response problems. If its representativeness for DOE can be established, it can be a useful measure of the pay practices for this substantial part of the energy R&D universe. Its principal deficiency is lack of occupational identification.

Earnings data on a relevant universe are only one part of an analytical process requiring comparisons. The other parts require data on:

1) The universe other than R&D, so that comparisons can be made of R&D S&E personnel with scientists and engineers not engaged in R&D, where mobility can be assumed to take place when pay differences are sufficiently great;
2) The specific local universe of R&D practitioners whose earnings are being compared with the universe of all R&D practitioners.

The first area of data -- the broad non-R&D universe -- is found, imperfectly, in a variety of sources. The BLS-PATC survey data (BLS 1) serve for a few limited occupations, those of chemist, engineer, and engineering technician. These data have the virtue of distinguishing the precise levels of responsibility that are important factors in differentiating salary levels. The survey serves as the data base governing changes in the entire Federal pay structure, and sensitivity about its integrity and the clarity of its intended purpose may present difficulties in using it as a vehicle for other purposes. It nevertheless seems worthwhile for DOE to explore with BLS the possibility of adding other occupational categories to the survey or expanding the basic data collection in other ways, such as identifying the R&D function of the presently included chemist and engineer occupations.

The obvious use of data from the NSF-Civil Service files on Federal Employment of Scientific and Technical Personnel (NSF 10) is for comparison of DOE and DOE-Contractor compensation with that of the Federal Government as a whole, to answer such obvious questions as, does DOE have more high or low graded personnel than in the Federal structure.

Other general pay sources are too broad and lacking in detail to serve for occupational pay comparisons, although they may provide useful indicators of trend or of shifts in labor market conditions.

For the second part, data for comparing the overall R&D universe with the local universe of the DOE and DOE supported facilities, the basic source should be that of the internal reports of the DOE and the operating reports of its contractors. The need for more detailed occupational data in the reporting system of DOE and its contractors is discussed elsewhere. It is a move that is high in priority if the end benefits of the information system are to be realized.

From a practical viewpoint, not all of the additional detail needed for earnings analysis can be included in the regular reporting system without making the reporting burden onerous. Some of the detail can be included in sample surveys of DOE and its facilities on a less frequent basis than the other regular reports. The present ERDA National Survey of Compensation and its comparison analysis rely on detailed reports from 18 ERDA laboratories (ERDA 9). This survey will probably continue to be conducted on a regular basis for the 18 facilities, but it needs some occasional, less frequent confirmation of what they represent in all of DOE.

d. Further Initiatives for Improvement and Development of Data Sources

The major areas of improvement have been outlined above. No new source of basic data is envisaged, except to the degree that provisions for collecting earnings data should be made wherever feasible within other vehicles that may be launched with respect to employment or other aspects of energy R&D manpower. As we have noted, salary data with occupational detail should be an essential component in the refinement of DOE and contractor operating data. If other existing sources of earnings data are sufficiently extended or improved, new sources need not be developed.

3. Exits and Interim Flows in Employment--Turnover, Mobility, Immigration, Deaths and Retirements

a. Introduction

In assessing the factors influencing supply highly trained manpower in specific occupational categories, the traditional primary focus is on levels of current employment and on initial career entries into the occupational categories from educational institutions in which training for these occupations takes place. The assessment is obviously not complete, however, unless other factors are also considered: ultimate exits from employment through death and retirement and interim flows into and out of the occupations reflected in job turnover, transfers in occupations and immigration and emigration. Shifts in these interim flows sometimes are signals of change in the balance of supply and demand within the occupational field; sometimes they reflect the spillover of supply/demand forces in other occupational fields or in other countries; sometimes they are the result of totally exogenous factors and affect rather than reflect supply/demand forces within the occupation.

Each of these conditions and vehicles of flow has to be considered in assessing current and estimating prospective supply/demand situations. The measures reflecting these flows can also, when correlated with other data within the manpower information system, supply answers to other needs. The information can, for example, be used by officials concerned with efficient manpower utilization or with special problems in personnel management, or by prospective career entrants and personnel officers concerned with job replacement opportunities (as well as employment growth); or by those concerned with broader social and economic issues implicit in immigration and retirement developments or in developments relating to the layoff and quit components of job turnover.

Unfortunately, data sources on these factors are widely disparate in coverage, quality and statistical treatment, and broad gaps exist in the information on some of the component subjects.

b. Data Sources

i. Turnover

a) Report of Contractor Employment and Turnover (ERDA 2). This is

113

based on semi-annual reports to ERDA's Division of Labor Relations by each Government-Owned, Contractor-Operated (GOCO) facility. These 60-some facilities employ about 90,000 persons, approximately 40 percent of whom are scientists and engineers. The reports are aggregated for publication by type of facility and show 6-month total separations by component (layoffs, quits), accessions, employment at end of period (as base for turnover rates) and promotions. Detail is given by sex, minority status and occupational category for individual contractors. The occupational categories are extremely broad, for example, all professionals, all technicians, etc. This broad classification of "professionals" tends to limit the usefulness of the data in identifying the turnover behavior of the many different occupations within this classification. Since so many different occupations are included in this broad classification, the usefulness of the turnover data is limited for identifying specific patterns and developments within occupations. They can, however, serve as useful indicators of general responsiveness to market conditions by professionals as a whole.

The data are mainly intended as guides to management, particularly for comparisons by individual GOCO establishments to the norms on nature and extent of personnel turnover, and on adherence to GOCO employment and promotion policies relating to women and minorities.

Additional analytical use can be made of the data as reflections of manpower demand forces affecting government-owned vis-a-vis private facilities engaged in energy activities, or vis-a-vis other facilities employing similar occupational categories of personnel. This kind of analysis would, however, depend on the availability of comparable data (in statistical treatment and coverage) for the other sectors to be compared. Such data are scarce, except for broad aggregates by industry covering employed populations markedly different from those in GOCO's. The other major measure of labor turnover, that of BLS, is only crudely applicable to the GOCO measures relating to professionals in energy activities.

b) <u>Current Labor Turnover Survey</u> (BLS 3), is conducted by the Bureau of Labor Statistics of the U.S. Department of Labor. This comprehensive source of industrial turnover data covers <u>all</u> employees in mining and manufacturing industries. The reports show monthly rates of all hires; new hires;

total separations; layoffs; quits; and other separations. No occupational identification is given; hence comparisons with GOCO turnover data cannot be made for analogous work populations. Inasmuch as nearly half of the GOCO work force are scientists and engineers, and a much smaller proportion of the manufacturing work force is in these occupations, comparisons of BLS factory worker turnover trends to GOCO turnover trends are somewhat strained. However, identification of specific energy industries can be made in the BLS survey, and the estimates can be useful in showing the overall state of the labor market in these industries for all occupations, as indicated by the rate and composition of personnel actions. To the extent that the general state of the labor market in energy industries affects the labor market situation of scientists and engineers (and such an inference may be warranted when the industries are expanding or contracting rapidly), BLS factory labor turnover data can be peripherally useful for confirming trends shown by other indicators for scientists and engineers. Turnover data in general have been regarded as key indicators of tightness or looseness in labor supply. Changes in quit rates are regarded as reflecting workers' perceptions of ease or difficulty in finding other employment. Quit rates do in fact vary inversely with layoff rates and directly with employment trends: expanding job opportunities accompany rising quit rates.

c) Other Turnover Information. Some other turnover data have at various times been developed for special purposes. The newest contender is that of the Bureau of National Affairs (BNA), which has developed turnover and absence rates, with a smaller sample than that of BLS, for a wider array of industry sectors. These go beyond the BLS coverage of manufacturing and mining industries to include other non-manufacturing, particularly finance and health industries. The information is a generalized reflection of labor market conditions and the specific application to energy manpower is remote. The data at best provide a background against which to examine work patterns that may be revealed among scientists and engineers by other data, and which may otherwise not be explicable.

ii. Mobility--Transfers to and from Other Occupations. An assessment of potential supply of scientists and engineers should include information on shifts into and out of (and among) their occupations. Relevant information would include that on employment changes between one energy field and another, between energy and non-energy fields, and between in and out-of the labor force status. It should also include information on shifts between the field of training and the field in which employment actually occurs, since a number of empirical studies have shown substantial differences between the university field of training and that of the career either initially or ultimately engaged in. If the parameters of allied fields of recruitment for a given field of employment can be determined, either by establishing the range of employer specifications for filling jobs or by determining empirical hiring patterns, more accurate assessments can be made of the potential labor supply for specific energy occupations.

Some information is available showing that a substantial proportion of the personnel working in scientific and technical occupations got into this work as a result of experience in other occupations, rather than through formal education or training that directly prepared them for their present occupation. In part, this reflects the breadth of education received: students nominally majoring in one field often take courses that give them background relevant to other occupations as well. Much of basic engineering education is a common core of all engineering specialties, and most science students take courses in a number of sciences. Among the large proportion of students who dropped out of college or graduate school before getting a degree but who had learned a substantial amount about various scientific fields, there are some who, having begun work in other occupations, are able later on to get a job in a scientific or technical occupation. Part-time study while at work is another way in which people are able to achieve occupational mobility.

These facts help to explain the substantial degree of mobility from other occupations into various scientific and technical fields. Among the relevant sources of mobility information are these:

a) BLS Mobility Studies Based on 1970 Census of Population Data (BLS 4)* show that, for all workers, 20 percent of those employed in 1970 had been in different specific occupations in 1965; among professional and technical workers it was 15 percent; 24 percent of the engineers; 35 percent of the computer specialists; 27 percent of the mathematics specialists; 22 percent of the life and physical scientists; and 27 percent of the engineering and science technicians employed in 1970 had been employed in different occupations in 1965. (Because of the inclusion of changes from the "occupation not reported" in 1965 to various occupations in 1970, those inflows may be exaggerated somewhat.)

While much of this movement reflects transfer among individual scientific and technical occupations, a certain proportion of it involves transfers from other, unrelated occupations. Among young workers this often represents movement from a job held while a student to a scientific or technical job held 5 years later after graduation; among older workers it more often represents true upgrading.

To get real insight into these movements, analysis should be made, for each occupation, of the occupations from which workers come, and the age, sex and educational characteristics of the persons who make each transfer. The bare essentials of the data required are available in the tabulations of the 1965-1970 census data; more significant information on educational attainment and field of degree can be obtained from the post-censal surveys of scientific and technical personnel. For both data sources, sampling variability will make it difficult to analyze specific occupational shifts by personal characteristics. Among the striking findings of the 1965-1970 census data is the very high occupational mobility rate of young men: half of those

* Five percent of the population were questioned during the 1970 Census of Population about their occupations and industries in 1965 as well as in in 1970. Part of the data was included in Census Public Use Samples, from which BLS was able to reaggregate data for a sampling of 3 percent (instead of the original 5 percent) of the population. By ingenious cross-tabulations and analyses, BLS tracked occupational shifts between 1965 and 1970 by origin and destination. For the analysis and some of the tabulations, see Dixie Sommers and Alan Eck, "Occupational Mobility in the American Labor Force," Monthly Labor Review, January 1977. See also the note therein regarding availability of additional analyses and tabulations. Some of these are planned for future publication.

who were 16-29 years of age in 1965 were in a different detailed occupation 5 years later, as compared to about one-third for the young women. Among both men and women the mobility rates were substantially higher for younger than for older workers.*

Geographical mobility can theoretically be a factor affecting the supply/demand balance of energy manpower, but geographical imbalances of manpower have not often been cited as a barrier to achievement of manpower objectives in R&D activities. That is to say, locational differences between supply and demand are not generally held to be responsible for failures to fill or find STP jobs, although specific individuals have undoubtedly made themselves unavailable for jobs in some locations, and some locations (Los Alamos comes to mind as an example) have had to offer compensating amenities and perquisites to offset difficulties of family life in the work area. In general, however, the high income levels of scientists and engineers, combined with a popularly reputed high mobility mystique associated with those professions, has diminished the importance of geographical imbalances as a factor in their manpower supply and demand.

b) <u>National Sample of Scientists and Engineers</u> (NSF 15) (cited previously). This sample from the 1970 Census, surveyed biennially as a longitudinal survey, would appear to be the ideal instrument for tracking the occupational shifts of those reporting themselves as scientists and engineers in the 1970 Census. Because it is a fixed cohort sample, new entrants into S&E occupations are not included, and the identification of the sources of new manpower supplies either from other occupations or from school at completion of training, or from various "holding pattern" statuses which characterize student, teaching or research support programs at various degree levels would, of course, not be shown. (The holding pattern statuses provide a significant potential source of supply for some disciplines. For example, 48 percent of all new Ph.D chemists in 1975 -- compared with 16 percent in 1960 -- were engaged in supported post-doctoral programs of study, teaching or scholastic based research. This group can in some respects be considered to be available to meet fore-

* Sommers and Eck, op.cit., p.15.

seeable increases in industrial and government demand for chemists.* Empirical information on the job mobility of this and other S&E groups would add materially to our knowledge of potential supply.)

The national sample does, however, permit us to trace shifts out of S&E work and shifts among categories of S&E work. When the survey has been continued for several more cycles, the patterns of shift shown by the survey could provide a basis for judgment on the flexibility of various sources of specialized manpower to meet potential demands for manpower to perform energy RD&D. Unfortunately, significant analysis of mobility patterns over periods of time is yet to be performed in the National Sample, since the longitudinal structure of the sample was established only in the survey of 1974. Future surveys and analyses should permit a better determination of patterns of occupational (and possibly geographical) shifts within the cohort and attritions from it, but unfortunately no basis for establishing the magnitude or origin of entrants into the occupations.

iii. Occupational Attrition Resulting from Deaths. For losses resulting from death, the best available method of estimation is the Life Tables developed by the National Center for Health Statistics, Department of Health, Education and Welfare.** These tables show annual death rates by age and sex. The rates can be applied to the members of each occupation for which the number at each age, by sex, is known. Occupational data by age and sex are available from the Census of Population, from the post-censal surveys of scientific and technical personnel, from the Ph.D roster maintained by the National Research Council (NRC 2) and from various other sources on specific occupations.

There is some evidence from data for 1950 that death rates for each age and sex group differ among occupations, and therefore the average rates for all persons may not apply exactly to specific occupations. The data reflect the effects of health hazards and life styles prior to 1950 that probably differed more among occupations than is true today. Moreover, those data

* See discussion in Professionals in Chemistry, 1976, American Chemical Society, Washington, April 1977, p. iv.

** Mortality in 1950 by Occupation and Industry, Vital Statistics: Special Reports, Vol. 53, 1961-1963. (issued by Department of HEW) have serious technical drawbacks. They are based on occupations as shown on death certificates, which typically ask for "usual occupation", and the occupations reported are in many cases different from those at time of death. Moreover, since 1950, with improvements in provisions for medical care such as Medicaid and prepaid health plans, with reductions in industrial accident rates, with greater availability of retirement options (Social Security old age and disability pensions and private pension plans), it is not likely that occupational differentials in mortality have been reduced but it is also likely that fewer workers die while employed. Deaths have become a smaller proportion of total occupational attrition, and any error in the estimate of deaths results in a less significant error in the total. By one estimate, deaths amounted to only one-quarter of the combined losses from death and withdrawal from the labor force from 1965 to 1970.* Therefore, the life tables for the entire population may be a reasonably accurate way to estimate the mortality losses from each occupation, or for any group for which the age and sex composition is known.

iv. <u>Occupational Attrition Resulting from Retirements</u>. The traditional method for estimating deaths and retirements is to use tables of working life, which show the expect annual attrition at each age for the male or female labor force as a whole, and to apply this to information on the age composition of the members of each occupation.

The implied assumption that all occupations are subject to the same age-specific attrition rates is recognized to be imperfect, but no better methods have been available.

Recent research has developed occupation-specific information on retirements, and, separately, on transfers to other occupations, using several bodies of data -- comparison of reports from individuals to successive surveys of the Current Population Survey of the Bureau of the Census as to their occupational attachment and labor force status; reports in the 1970 population census as to each individual's occupation and status in 1965 compared with 1970 (BLS 4); occupation and labor force status as reported in National Sample surveys of scientific and technical personnel (NSF 15) as compared with status in 1970; and reports on the National Longitudinal Surveys conducted for the Labor Department by Ohio State University.**

* Sommers and Eck, op. cit., p. 9

** See "Comparisons with other Data" discussion in Sommers and Eck, op. cit., pp. 14-17.

The source that potentially is most generally useful is the population census question on occupation and status 5 years earlier (BLS 4). While there are technical problems that make it difficult to interpret the data (notably, accuracy of recollection of occupation 5 years earlier, the large number of persons shown as "occupation not reported" for 1965, and misclassification of current occupations either in the respondent reports or in tabulations), the data show reasonable differential patterns of retirement, consistent with patterns coinciding with the age composition of occupations and the freedom of choice workers have to continue to work in various occupations (e.g., self-employed vs. employees).

Since people who leave the labor force sometimes return subsequently, especially women, the data on retirements covering 5-year periods are more reliable as indications of more permanent retirement than those for shorter periods.

This can be seen in the fact that monthly separation rates for all occupations, as shown by the Current Population Survey, averaged 4 percent in 1970; annual rates, as shown by the same source for 1973-74-75, averaged 8.6 percent rather than 12 times the monthly rates; and the 5-year rate, as shown by the 1965-70 data in the population census, averaged 14.8 percent, instead of 5 times the annual rate. Similarly, the 5-year rate in scientific and engineering occupations averaged less than 2.5 times the 2-year rate shown in the post-censal survey of those occupations.*

Typical 5-year retirement rates for scientific and technical personnel shown in the 1965-70 tabulations from the 1970 population census were 4.6 percent for engineers, 6.5 percent for physical and life scientists, and 6.0 percent for engineering and science technicians. Adding the death rates calculated by applying age-specific mortality rates for all men and women to the age composition of each occupation as shown in the census, average annual attrition from both retirement and death may be estimated as 1.9 percent for engineering, 2.1 percent for physical and life scientists, and 1.9 percent for engineering and science technicians.** The data are available for specific

* Ibid, p. 17.

** Ibid, p. 9.

engineering, scientific and technical occupations.

v. Transfers to Other Occupations. Data on transfers are available from the 1965-1970 tabulations of changes in occupational status in the 1970 census of population (BLS 4), from the post-censal survey of 1972 (NSF 14), the subsequent biennial surveys (1974 and 1976 from the National Sample of Scientists and Engineers (NSF 15), and from the National Longitudinal Survey (but only for a few selected age groups and for a sample too small to give adequate occupational detail).

The 1965-1970 data are subject to errors of recall of 1965 status and occupation, and to failure to report 1965 occupation. The combined impact of these errors is estimated to be an average 14-percent overestimate of transfers to 1970 occupations and a 6-percent overestimate of all other entrants to 1970 occupations (i.e., from outside of the labor force and from the Armed Forces).

The transfers shown by the biennial national sample surveys (NSF 15) are not subject to the error of recall, since the 1970 occupations were reported at the time. Errors of reporting, or of coding by the Census Bureau may, however, be present. Another source of potential error is failure to get reports from all persons in these surveys, which may be associated with greater changes in occupational status than was true of those reporting (i.e., persons who moved and changed jobs or retired were less likely to report than those who remained in the same place and job).

On balance, the 5-year patterns of change in occupation may be better than the 2-year patterns for projecting future changes, since the latter are more subject to reverse shifts -- changes back to the original occupation or status -- while the 5-year changes are more likely to represent more permanent shifts.

The data are useful in measuring the substantial amount of occupational mobility that occurs in the United States, even in highly skilled occupations requiring long periods of training, such as scientific and technical fields.

Some notion of the extent of S&E job mobility is revealed by the 1970 Cenus data. Among persons who were engineers in 1965, 16.8 percent had transferred to a different occupation by 1970; among life and physical scientists, 19.4 percent; among engineering and science technicians, 30.0 percent. These figures may be compared to an average for all occupations of 30.2 percent; i.e., the rate of transfers out of engineering and scientific occupations was less than that for all workers.* A substantial proportion of the transfers were probably to managerial or other scientific and technical occupations. The usual patterns of mobility to other occupations can be determined by examination of unpublished tabulations available at the Bureau of Labor Statistics or Bureau of the Census.

The same errors noted for this source and the related surveys that can be used to check the data, as described in the section on Retirements, above, apply to the use of the information in measuring transfers to other occupations.

Transfers are also affected by economic circumstances, particularly the labor market situation in each occupation in relation to that in other occupations open to the same individuals. Transfer rates, and the occupations to which workers transfer, will probably differ from time to time, depending on these circumstances. The effect on the supply of scientists and engineers available for energy RD&D can be substantial, either to increase the supply if the economic demand is comparatively high, or to decrease it if demand in other fields is higher and induces attrition in energy RD&D occupations.

This lends additional emphasis to the recommendation that the questions about occupation 5 years earlier be repeated in every Census of Population, as well as the recommendations for technical improvement in the data and sample size.

Recommendations:

1. In order to make better mobility data available, the Bureau of Census should be urged to continue to collect the data on occupation 5 years earlier in each population census; to collect them on a sample larger than 5 percent, and to make the tabulations of 5-year-ago status and present status using the whole sample collected, rather than just the Census Public Use Sample, which permits putting together a sample of only 3 percent. This

* Ibid, p. 9.

would make it possible to obtain usable data on small occupations (for 19 scientific and technical occupations the retirement loss estimates were not published because their relative errors were more than 10 percent). The Bureau of the Census should also be urged to take steps to improve the accuracy of reporting; this may involve research on factors affecting the accuracy of reporting both for current and previous occupations. The Bureau of Labor Statistics, which has tabulated the data in individual occupations extensively for potential use in manpower analysis, should be urged to eliminate persons shown in the data as "occupation not reported" and to make tabulations in which both the number of persons transferring into and the number transferring out of each occupation can be calculated as a percentage of the number in the occupation in the earlier year, so that the net transfer rate can be estimated.

2. While the 5-year retirement data are better than those for shorter periods of time, particularly in occupations with significant numbers of women, other sources of data such as the Current Population Survey tabulations and the results of longitudinal surveys should be used to check the data from census questions on occupational status 5 years earlier. These alternative sources are not subject to reporting error resulting from lapses in memory. The National Sample surveys may miss some persons who retired or left the occupation, as a result of a differential non-response rate that may reflect lack of interest in scientific and technical occupations.

The patterns of occupational retirement rates for 1965-1970 reflect the labor market situation and the availability of retirement benefits as of that time. Subsequent repetitions of the surveys may show a range of retirement rates under different economic circumstances.

vi. Immigration and Emigration. Immigrants contribute substantially to the American supply of scientists and engineers. During 1966-70, when S&E immigration was at a high point for recent times, the number of scientists and engineers entering as immigrants each year was equivalent to about one-fourth of the annual net increase in U.S. employment in these occupations. Even though S&E immigration in the past few years has declined by almost half from the 1966-70 rate, the net addition to domestic supply must still be accounted as substantial.

Some of the immigration is a response to the comparative high intensity of U.S. demand or to the higher pay and higher quality of employment here -- or to the immigrant's perception of these factors. Some of the immigration reflects exogenous factors, such as political or religious repression in the country of origin, or the relaxation there of exit controls. In a study by the NSF of characteristics and attitudes of alien scientists and engineers who were permanent residents of the U.S. in 1969, the reason for entering the U.S. was most often to seek a higher standard of living (NSF 19). By individual country of birth, however, the primary reasons for emigrating varied -- economic factors, for example, primarily influencing those from the United Kingdom, political factors those from Cuba, and insufficient opportunities to do research those from India and China.

In the operating statistics of the Immigration and Naturalization Service (INS) we possess an established data source, even though it is imperfect, on the number and kinds of immigrants; but there is no authoritative source of data on the reverse movement -- emigration. This data gap is significant, since ad hoc and fragmentary studies indicate that there is a substantial outflow of potential U.S. manpower supply, which may be quite high among foreign born American citizens or foreign citizens awarded degrees at schools in the U.S.* (Most of the latter should not be termed emigrants.)

* Robert Warren, "Recent Immigration and Current Data Collection," Monthly Labor Review, Washington, October 1977, p. 40. Warren's conclusion is based on data collected until 1957 by the Immigration and Naturalization Service on emigration of aliens. Between 1908 and 1957, 15.7 million immigrants came to the United States, and 4.8 million aliens emigrated. Also cited in this article are estimates of American citizen emigration based on records of other countries, in Ada Finifter, "Emigration from the United States, An Exploratory Analysis," prepared for the Conference on Public Support for the Political System at the University of Wisconsin, Madison, August 13-17, 1973. In addition, significant proportions of new doctorates are awarded to foreign citizens, e.g. 22 percent in physical sciences, 42 percent in engineering, 24 percent in mathematics, and 37 percent in agricultural fields. Using data on planned region of employment for these doctorates, NSF has estimated that an average of ten percent of all science and engineering doctorates obtain foreign employment. (Source: NRC 1). This outflow would be an offset to the estimate of new domestic manpower supply from among graduates.

Emigration data are plainly more difficult to collect than immigration data, unless international cooperation can be developed to pool the immigration reports of all major countries on a basis that shows and permits summarization of country of origin. There is a precedent for this kind of cooperation to produce consolidated data (or data that can easily be consolidated) in the export and import operations of the country members of the General Agreement on Tariffs and Trade. We believe that information on international movements of manpower is sufficiently important to warrant positive efforts to obtain the international agreements that would develop such information.

Immigrants are admitted to this country under a series of preferences specified by the Immigration Act of 1965. Four basic groups of preferences are reserved for: 1) relatives of U.S. citizens or aliens who reside here permanently. 2) persons in shortage occupations, 3) certain refugees, and 4) all other applicants up to the quota limit. Many aliens gain formal immigrant status only after their entry into this country under a variety of temporary visitor categories, in which they are considered non-immigrant aliens. Non-immigrant aliens contribute to the temporary supply of scientists and engineers as students, gifted temporary visitors, exchange visitors, industrial trainees and intra-company transferees. Many of these subsequently become permanent immigrants. Although under some conditions of shortage it might be necessary to look to non-immigrant aliens to supplement the domestic supply of scientists and engineers, the assessment of foreign sources of S&E manpower can for most purposes be more practically limited to permanent immigrants.

The primary sources of data on immigrant scientists and engineers are these:

1. Beneficiaries of Occupational Preferences and Other Immigrants Admitted, by Occupation, published in the Annual Report of the Commissioner of Immigration and Naturalization (INS 1).

These tables show the occupations declared by immigrants in their applications for immigrant visas according to two broad classifications of entry: entry under occupational preferences, and under all other preferences. The "all other" preferences cover relatives of U.S. residents and residual quota entrants and account for the majority of all immigrants as well as the majority of scientists and engineer immigrants.

Tne data are deficient in two respects: the occupational identification is made by the applicant for immigrant status, and the perceptions and usages of foreigners in occupational terminology are not always in accord with those in this country. Moreover, the occupations listed are those of the applicant before gaining immigrant status; no regular follow-up is made to determine the occupation of actual employment after immigration.

2. Scientists and Engineers from Abroad: Trends of the Past Decade, 1965-76, published by the National Science Foundation in "Reviews of Data on Science Resources" No. 28, February 1977 (NSF 16).

These reports are based on INS data, retabulated and analyzed by NSF specifically from the point of view of examining scientist and engineer supply from abroad. Although this is strictly speaking an ad hoc secondary source, the retabulations serve to correct and refine the original data (some of which are not published) and place them in perspective with a variety of trends and factors relating to the contribution of S&E immigration to U.S. supply. These special tabulations, analyses, and comparisons with other relevant data therefore provide a reference base for understanding the current data reflecting INS operation of the immigration program.

3. Immigrant Scientists and Engineers in the United States - A Study of Characteristics and Attitudes - Bulletin NSF 73-302 of the National Science Foundation (NSF 19).

This represents one of the few attempts at follow-up of immigrant scientists and engineers. It is based on a sample of immigrant residents of the U.S. in 1969 who attained immigrant status between 1964 and 1969 and reported themselves employed as scientists and engineers in the regular annual alien registration in 1969. The survey developed information on reasons for immigrating, demographic and educational characteristics, employment status and appraisals of living and working conditions in the U.S. Unfortunately, the survey was not based on immigrants who reported themselves as scientists and engineers in their application for immigration (since the application records were not consolidated or easily accessed); hence no comparisons could be made between the declared occupation of the alien entrant (the basis for the INS immigrant occupation data) and his subsequent U.S. employment.

4. A number of other studies have been made of immigrants as a source of manpower supply in the U.S., but few of them focus or contain significant information on scientists and engineers. Among those sponsored by the U.S. Department of Labor's Employment and Training Administration on legal and illegal aliens is one which is relevant, in a general way, to the issue of occupational identification of applicants for immigration and their subsequent occupation of employment. David North's "Immigrants and the American Labor Market," (Manpower Research Monograph No. 31, U.S. Department of Labor, Washington, 1974) reports on a comparison between occupations declared on visa applications and a follow-up of subsequent employment. The basic information, incidentally, was obtained with great difficulty only after special efforts by the INS, DOL, and the project staff. Significant among the findings was that of substantial slippage between the stated occupation before immigration and actual occupation afterwards. Unfortunately, the level of detail did not go below the broad category of professional and technical occupations to identify scientists and engineers, but the findings at the broad occupational levels was that of slippage downward from the reported occupational categories with traditionally high socio-economic status, and mobility upward from the occupations with traditionally low socio-economic status. While the conclusions of this small-scale study are not definitive, they point to the need for further exploration of the occupational information on immigrants and for better accessibility of data to make such exploration.

Recommendations:

1. DOE, in cooperation with INS and other interested agencies, should examine how technical support can be given for the improvement of statistical operating data on immigration, with particular emphasis on improved classification, tabulation and publication of occupational information on applicants for immigration, and for the consolidation of the original application data so that they may be accessed for special analytical needs, with due regard given to the confidentiality of these reports. DOE should urge INS to include more detailed instructions in the application for immigration, and more detailed instructions should be supplied to consular officials to improve the accuracy of occupational designations of applicants for immigration. Checklists and definitions should be supplied on critical occupations and on those subject to preferential admission.

2. DOE should urge that occasional follow-up surveys be made on the employment status of immigrants. A key objective should be to trace the employment contributions of S&E immigrants subsequent to their stated pre-immigrant occupational designation.

3. DOE, in cooperation with INS and other interested agencies, should examine the feasibility of developing information on the emigration of U.S. scientists and engineers, in order to fill a significant gap in our knowledge of S&E supply. As a first step, the INS should be asked to consider the reinstatement of data collection on emigration of aliens from the U.S. that it conducted from 1908 until 1957. Emphasis should be given to collection of occupational information. Additional and more extensive studies such as those of Ada Finifter (previously cited) should be devised to develop emigration data from the immigration records of other countries. The example of consolidated data on imports and exports by country of origin and destination, now commonly exchanged by signatory nations to the General Agreement on Tariffs and Trade (GATT), should be considered as a precedent and model procedure for extension to immigration data through other international bodies. The DOE should ask the State Department to initiate such a move with the Organization for Economic Cooperation and Development (OECD). If consolidated immigration-emigration data prove feasible and useful in the OECD, as we believe it will, institution of such data in the wider sphere of the UN should be considered.

4. Measuring the Current Balance of Supply and Demand

Some of the data needed to assess the labor market situation in occupations identified with energy RD&D have been described above in the sections on earnings and mobility of labor supply. This section will discuss other indicators of labor market dynamics that are particularly sensitive to changes in supply and demand, such as data on the placement experience of graduates, statistics on job applicants in the public employment service, want-ads, and immigration and emigration.

a. Placement Experience of Graduates

The current labor market supply/demand situation is revealed in part by the comparative experience of graduates in scientific and technical specialties in getting jobs and the salaries they are offered or paid. This experience is shown by systematic follow-up surveys of a cross-section of graduates some months after graduation, to ascertain what jobs they found, whether or not the jobs were in their specialties or in related fields, and the salaries paid. Several such surveys have been made.

i. NSF Survey of Science and Engineering Graduates (NSF 18). In 1976, The National Science Foundation (NSF) contracted with Westat, Inc. (Rockville, Maryland) to conduct a follow-up survey of science and engineering graduates at the bachelors and master's degree levels. The survey sample was over 7,000 at the bachelor's level for two graduating classes and nearly 1,000 at the master's degree level. NSF has again contracted with Westat to conduct a similar survey in 1978, covering graduates of academic years 1972 and 1977. The survey plan includes a sample of 1,000 bachelor's and 570 master's recipients for each year and for each of seven groups of science and engineering fields -- amounting to a total of over 21,000 names. Data will be collected on such subjects as: age, sex, race, field of degree, employment status (including science and engineering fields, type of employer, salary, work activity, field of critical national interest, such as energy, and support by Federal agency). The problem of non-response to mail questionnaires -- always a weakness in follow-up surveys because of the possibility that non-respondents may differ from respondents in such characteristics as success in finding a job in the field -- is being worked on seriously by the survey agency in an attempt to minimize its effect on the validity of the figures.

Recommendations: This survey has the greatest potential for giving DOE a picture of the current labor market for graduates in scientific and technical occupations, since the sample is large and concentrated on graduates in these fields, and since salary, work activity and involvement with energy are among the items collected. DOE should work with the sponsoring agency to assure that the field-of-degree and field-of-work tabulations meet DOE's special needs.

ii. NCES Surveys of College Graduates (NCES 5). A survey of college graduates of 1974-75 was conducted for the National Center for Educational Statistics by Westat, Inc. in 1976. It focused on producing estimates of the supply of new teachers, but included a cross-section of all college graduates, 4,000 with bachelor's and 1,000 with master's degrees. The response rate, 79 percent, was good for a follow-up survey. The numbers of graduates in scientific and technical fields were too few to give information on unemployment and under-employment for specific engineering and science fields, and while an estimate of those employed as engineers is being published, no separate figures were available for the numbers employed in scientific occupations. This survey is therefore not as useful for DOE's purposes as the survey done by the same firm for NSF. It does, however, show the number of graduates with degrees in other fields who get jobs in scientific and technical fields. Moreover, it has value in setting the labor market picture for scientific and technical personnel within the general context of the market for other types of graduates. If the market in scientific fields is substantially different from that in other fields there may be a tendency for students to shift to the more favorable fields. NCES has contracted with the National Opinion Research Center to conduct a similar follow-up of 1977 graduates.

Recommendation: DOE can utilize the results of this survey in tracing shifts into and out of scientific and technical fields and in appraisal of future supply of workers in scientific and technical occupations, and should urge the NCES to get breakdowns of both the degree fields and the fields of employment that are relevant to DOE concerns.

iii. College Placement Council surveys (CPC 1). A more timely, but less accurate, picture of the labor market for scientific and technical graduates may be obtained from surveys made by the College Placement Council, Bethlehem, Pa., and by Northwestern University, Evanston, Ill., both of which have been described under Earnings, above.

The College Placement Council data are based on a sample that is not necessarily representative, and reporting is incomplete since not all offers are reported by students. The numbers of offers can only be evaluated by year-to-year comparisons, which are partly invalidated by changing samples and changing styles in recruitment activities unrelated to suppy and demand. In summary this survey's results are a straw in the wind, and far from definitive, but they add to an appraisal of the current situation.

iv. Northwestern University ("Endicott") Surveys (NWU1). This annual survey reports each Fall how many graduates large companies hired in the past year and at what salaries, and how many they intend to hire in the coming year, and the salaries to be offered. In the report, intended hires and salaries are compared to those for the previous year, by degree level, occupation and sex. From this it is possible to judge whether or not the market for graduates is changing.

The sample is, of course, not representative of the entire market, since it omits small employers, universities and government agencies. It does, however, present a more complete picture for these large firms, unlike the College Placement Council survey (CPC 1), which misses any job offers graduates fail to report on. Occupational detail is not as specific as could be desired: the only technical occupations reported are engineering, chemistry, and mathematics/statistics. Employment of physicists, other physical scientists and biological scientists by industry is large enough to warrant separate reporting, and a request for inclusion of these fields should be made to the Council. Another suggestion that should be made is to tabulate comparisons of the actual hires with the intentions expressed on the previous year's hires.

Recommendations: DOE should suggest that natural scientists other than chemists be tabulated, and that tabulations be made comparing intentions to hire with actual hires by the same firm.

v. Surveys by professional societies. A number of professional societies make follow-up surveys of graduates in their fields, usually by sending questionnaires to officials of the schools or departments who keep in touch with their graduates. One of the best-established of these surveys is that conducted by the Engineering Manpower Commission of the Engineers' Joint Council (EMC-2). The coverage of engineering schools is very good, but, as with all follow-up surveys, a significant number of graduates are missed, and this could substantially affect the number shown as unemployed. Nevertheless surveys like this pick up the trends in the labor market effectively -- the number of bachelors' degree engineering graduates with no job offers rose from less than 1 percent in 1969 to 14 percent in 1976. Other major efforts of this type are conducted by The American Chemical Society, The American Institute of Physics, and The American Geological Institute.

b. Want Ads

Employer advertising of positions they want to fill has been found by the Conference Board to be a good measure of changes in the labor market situation, and an index based on the amount of classified advertising in newspapers throughout the country has been found to correlate well with the level of unemployment, and actually to move in advance of changes in unemployment; in other words, it is one "leading indicator" of labor market changes.

A similar index specifically for scientists and engineers, the Engineer/Scientists Demand Index (DSE 1), is compiled by the firm of Deutsch, Shea and Evans, in New York. It is based on advertising in newspapers and technical journals, and is issued monthly. No detail is given for individual occupations. The index can be viewed as a rough indicator of changes in the level of demand for scientists and engineers, but there is no claim that the sample of newspapers and journals is representative, or that the measure -- number of lines of type in classified ads and advertising in journals -- accurately reflects the intensity of demand. The index has to be used cautiously, and together with other indices.

Recommendation: DOE should suggest to the Deutsch, Shea and Evans organization that separate figures for such major groups as engineers, natural scientists, and computer analysts be tabulated; this would help to pinpoint the kinds of workers in demand, and it should be feasible since the advertisements usually specify the occupations sought.

c. Counts of Job Applicants

The operating statistics of the U.S. Employment Service and its cooperating State agencies provide information on changes in both manpower supply and demand. Their measure of the supply is the number of applicants in the files of the State employment services (ETA 1). While scientists, engineers and technicians do not typically use the public employment service as much as other channels for job-seeking, when jobs are particularly hard to get the number who use this service tends to increase. The applicant files, then, are a potential indication of the labor market situation in these occupations only when there is a surplus of job-seekers. The Department of Labor keeps a computerized file on applicants by occupation (with detail on several hundred occupations), and tabulations are made quarterly. The applicants include some who are employed but who want better jobs; they may be considered -- and probably consider themselves -- as under-employed.

The Employment Service measure of employer demand is that of unfilled Job Orders or Job Openings, that is, job orders that have remained unfilled or vacant generally as of the end of a calendar month (ETA 3). The most useful summary sources of these operating data are included in two monthly publications: Occupations in Demand (OID) and JOB-FLO, (Job Bank -- Frequently Listed Occupations). The reports are similar, but represent somewhat different samples of the total operating data based on different selection and inclusion criteria, and they take analytical approaches intended for different audiences. The OID publication is basically intended for guidance of the job seeker; JOB-FLO is of principal use to the labor market analyst.

Other placement data: The major professional societies conduct placement services usually at their national meetings, at which applicants and recruiters are given an opportunity to meet each other. Information on the numbers of applicants and the numbers of jobs for which recruitment is going on are often developed by the societies as a by-product of this activity, but not systematically collated and analyzed.

A uniform system of reporting on these placement activities might be a useful additional source of information. A way in which a start might be made in developing such a data source, and improving the placement process as well, is being shown in a demonstration job bank project supported by the U.S. Department of Labor with the American Agricultural Economic Association and the Illinois Bureau of Employment Security.* In that project a computerized file of agricultural economists' qualifications is being established for electronic matching against employer job orders. If a system like this can be made uniform among various professional societies, and reports on the job orders and placements then collated by occupation, a signficant new source of information on professional supply and demand would be produced.

d. Immigration and Emigration

Trends in movement into and away from the United States could reflect the labor market situation for scientific and technical personnel. Immigration dropped sharply after 1971, when there was an unfavorable job situation. At the same time, migration flows also reflect situations in other countries, an example being the large numbers of refugees from Germany and Austria in the period of Nazi ascendancy in the 1930's. Situations in countries of origin can be such that people want to get into the United States whether or not it is easy to get jobs. The reverse may also be true: life in general or employment opportunities in particular in other countries may be attractive to some U.S. residents regardless of the employment situation here. Also, immigration policies of the U.S. and other countries change

* "The Development and Assessment of an Experimental Full-Time Employment Service for Agricultural Economists," Grant 21-21-73-42. Project description in Manpower Research and Development Projects, 1975, U.S. Department of Labor, Washington, 1975, p. 7

from time to time, with a major effect on migration flows regardless of supply/demand situations. The present U.S. policy is such, however, that the domestic employment situation in the various occupations affects the ease with which immigrants with those skills are admitted. Moreover, most immigrants who are workers enter under preference quotas unrelated to occupational scarcities. On balance, migration statistics, while essential in evaluating changes in supply, are imperfect clues to the U.S. labor market situation.

Data on immigration and emigration are discussed in the section on labor supply, and the discussion will not be repeated here.

e. Unemployment

A good general index of the labor market situation for an occupational group is the unemployment rate.

The national data on unemployment available monthly from the Bureau of Labor Statistics, collected in the Current Population Survey of the Bureau of the Census, is regularly tabulated only by broad occupation groups, of which professional, technical and kindred workers is one. Data on unemployment rates are tabulated, but not usually published, on large occupations such as engineers. The reason why they are not usually published is the large sampling error associated with the unemployment rate for groups of this size. If, for example, the rate for engineers were to be reported as 2 percent, the chances are about two out of three that if a complete census had been taken instead of a sample survey that the rate found would be within the range of 1.4-2.6 percent, and there is one chance in three that it would be outside this range. A smaller sampling error can be achieved by averaging the rates for a quarter or for a full year. While this is hardly precise information, it adds an independent current indicator of the labor market situation in scientific and technical occupations nationally. No occupation data are available from this source for states or smaller geographic areas, nor, of course, for energy industries.

Recommendations: In appraising the current labor market situation for scientific and technical occupations generally, DOE should obtain unpublished unemployment information from BLS.

f. Summary Evaluation of Existing Data on the Current Labor Market

Information for analysis of the current supply/demand situation comes from a number of diverse data sources. While some are better than others, all should be consulted for whatever light they may shed on the situation.

Of the various surveys of the employment experience of graduates, the NSF survey of science and engineering graduates is the most valuable and relevant. Unemployment data for scientific and technical workers from the Current Population Survey and labor turnover data for energy and energy-related industries should be obtained. Information on job applicants at the public employment service and on immigration and emigration will be of value only occasionally.

g. Further Initiatives for Improvement and Development of Data Sources

A. A manpower intelligence network. DOE conducts and supports energy RD&D in a wide variety of programs, organizations, industries, fields of science or technology, and locations throughout the United States. Under these circumstances, staff project directors and personnel officers are aware of current supply and demand problems for personnel involved not only for their own unit but also for allied and even competing organizations.

It is recommended that this resource be tapped: that those responsible for manpower assessment in the Department establish a "manpower intelligence network" of key individuals in each intramural laboratory, GOCO organization, and possibly even in some other organizations working on DOE grants or contracts. These individuals would be asked to supply at intervals (such as every 6 months) a response to a half-dozen questions on the labor market situation for scientific and technical personnel. Among the types of information they might be asked to supply are: occupations (by specialty) for which recruitment problems are present or emerging; knowledge of similar problems in the DOE contracting network or even in other organizations; information on training deficiencies; unique or unusual changes in salary levels and unexpected turnover or mobility experiences (recruitment by competing organizations or other factors). Other items can be added as experience indicates.

The key to the success of reporting from the "manpower intelligence network" is to secure the cooperation of respondents without creating unusual reporting requirements.

C. EDUCATION AND TRAINING OF ENERGY RD&D MANPOWER

1. Introduction

Since much of the manpower directly relatable to energy research, development and demonstration programs consists primarily of highly-trained engineers, scientists, technicians, and selected craftsmen, most of the supply of manpower for these occupations flows from established programs in the nation's educational institutions, or other training centers. The current pool of persons employed on energy RD&D programs is augmented mainly either from new graduates and nongraduates of universities, colleges, and other institutions or from previously graduated scientific, technical, and craft personnel. Other sources of supply are of course immigrants and transfers from non-science and engineering fields or training.

However, most of the available scientific and technical manpower, not only for energy RD&D but for all R&D and also all other scientific and technical activities, are products of our educational system. Therefore, for basic information on current, as well as projected, supply and for assessment of its relationship to demand for personnel, it is vital that an adequate data system on the education and training of scientific and technical personnel be available. The level of educational activity affects the demand side as well, though to a lesser extent: the number of persons enrolling in and graduating from science, engineering, and technician programs create specific requirements for teaching personnel -- that may be competitive with energy RD&D and other requirements.

Our system for education and training as preparation for employment and careers and the actual employment graduates enter is not tight or precise. In most instances a graduate in almost any field can be said to have received an education much broader than his later jobs require. Our system of higher education -- universities and colleges, including community colleges and technical institutes -- produces graduates in subject matter areas, e.g. chemistry, aeronautical engineering, physics, or mathematics. But, in general, other than in a few specific areas, our schools do not graduate persons trained to work on energy specialties, such as coal gasification research or solar energy cells. The few exceptions are nuclear engineering, radiation protection (health physics), petroleum and mining engineers, or geologists and geophysicists, though some in the latter fields work on metallic or non-energy areas. It should be noted that many employers and educators of scientific and technical manpower support the system of more generalized preparation, since it usually is much broader than job requirements. Thus, employers can provide the more specific job related training or experience.

2. Major Statistical Sources of Information

There are several agencies, organizations, or groups of them which serve as the major sources of information on enrollments and/or degrees (or awards) granted in scientific and technical fields. The major sources of information or data collection systems are shown below. As indicated above most of these are sources for education and training of scientific technical, and craft personnel in general, not for energy R&D per se. Relevance to the latter specific area will be noted for each source. (See Appendix B for further description of these sources).

a. Higher Education General Information Survey (HEGIS)

This series of surveys brought together in an integrated package by the National Center for Education Statistics (NCES) of the Department of Health, Education and Welfare is the most comprehensive coverage of higher education data. Though the content changes somewhat over time, certain parts of the survey are standard. Such surveys which are of relevance to energy RD&D and related manpower include those covering associate degrees and other formal awards below the baccalaureate, upper division enrollment, earned degrees conferred, and students enrolled for advanced degrees. These surveys are conducted annually.

i. Associate Degrees and Other Formal Awards below the Baccalaureate (NCES 3). The survey covers all institutional units identified in the Education Directory (NCES) as a universe of those offering at least two years, but less than four years, of college-level work. The survey collects data on the numbers of associate degrees or similar awards offered in occupational curricula in a variety of technologies -- including data processing, health service, mechanical, engineering, and natural science technologies, business and commerce, and public service-related technologies. The survey also collects data on the numbers of completions in arts and sciences general programs. The questionnaire provides for the full taxonomy of technological and occupational curriculums in higher education.* A number of these specialties are directly or indirectly related to energy sources, including the following technologies: automotive, diesel, welding, electromechanical, instrumentation, nuclear, and laboratories. There is some degree of comparability over time; however, new specialties have been added and revisions made over the years. Data are available for individual institutions and information is classified by type of institution, type of control, sex of recipients of awards, State and other factors.

This survey of course does not cover all sources of post high school training which provide preparation for technical, semiprofessional, or even some professional jobs. The survey does not reach technical training in high schools, apprenticeships, Armed Forces, or on-the-job programs of employers.

ii. Upper Division Enrollment (NCES 4). This is a new section added to the HEGIS system for Fall 1975 to collect information on numbers of upper division (juniors and seniors) students by major field of study. It was combined with the established collection on students enrolled for an advanced

* Department of Health, Education, and Welfare, National Center for Educational Statistics, A Taxonomy of Institutional Programs in Higher Education, OE-50064, 1970.

degree. Information is provided on enrollments by field, sex, full- or part-time study, and by institution and geographic location. Separate data are obtained on students enrolled for first professional degrees. No data are obtained relating to energy, except for a few selected specialties such as nuclear, geophysical, mining or petroleum engineering, or geology and geophysics.

The Fall 1975 survey was the first such collection of such data since 1967. The National Center for Education Statistics is not certain how often this survey or that on enrollment for advanced degrees will be conducted. Both surveys appear to enjoy very high response rates and have no special trouble with definitions.

iii. Earned Degrees Awarded (NCES 1). The survey covers all institutions in the United States, its territories and possessions which awarded bachelor's, masters' and doctors' degree in any specialty. The approximately 1,800 institutions are identified in the Education Directory (NCES). Separate information is provided by level of degree, subject specialties, type of institution, State, and sex of degree recipients. Data are requested from the head of school or through State coordinators. Response is practically complete across institutions, but the degree of error or misclassification of degrees by specialties is not known. Comparability of fields of degrees goes back to 1970-71; some comparisons can be extended to 1965-66.

This is the only comprehensive source of information covering all recognized academic degree programs in U.S. schools. As such, it provides information on the potential flow of persons into scientific and technical manpower activities. Academic specialties covered are those in the Taxonomy of Instructional Programs in Higher Education and thus include many science and engineering specialties. Some of these are directly or indirectly related to energy RD&D areas, such as petroleum, mining, and nuclear engineering, geology, geochemistry, and metallurgy. However, as indicated previously there is no one-to-one relationship between the types of academic training received and occupation or job performed.

iv. Enrollments for Advanced Degrees (NCES 2). This part of the HEGIS survey solicits information on students enrolled for a masters, doctorate, or first professional (e.g. medicine, dentistry, law) degrees in all institutions included in the Education Directory (NCES). Response, from about 1050 institutions in the last survey, was practically complete. Information is provided on major field of study (taken from the Taxonomy of Instructional Programs of the NCES), sex of student, attendance status (full or part-time), by stage of study (in first year or beyond one year of study), by type and control of institution and state location. Individual institutional data are available.

As in the case of the survey of earned degrees (NCES 1), information on enrollments in fields directly or indirectly related to energy RD&D areas is available. However, the degree of relationship of those trained and those employed in such activities is not known.

This survey is the most comprehensive source of the data on enrollment students for graduate degrees in all fields of study. At each survey period, however, it excludes by definition a number of students enrolled in graduate courses, but not for a degree. Post-doctorates are also excluded.

Comparability by discipline is good back to 1970-71, when the present taxonomy was established. However, some comparisons can be made to 1965-66.

The HEGIS survey also provides a separate overall count of enrollment in which data are obtained on total graduate and undergraduate enrollments by institution -- but not by field of study.

v. Summary. The HEGIS surveys are tallies of the total universe of higher education institutions, rather than samples, and in most instances an almost complete response is accomplished. However, the time between the reference date and actual publication of official results of the individual HEGIS surveys is relatively long. Though arrangements are available for securing preliminary results, they are limited to those users with computer terminals linked to the HEGIS system. Another weakness of these surveys is the gaps in the taxonomies of programs relating to energy. (e.g., health physics, hydrology, etc.). Finally, with limited staff and resources for the HEGIS surveys, it is not always certain that selected surveys will continue in a planned fashion.

Recommendations: That DOE lend its support -- moral, financial, or otherwise -- to the orderly conduct of HEGIS surveys concerned with higher and post-secondary education. Emphasis should be placed on "making DOE needs known" -- fields of study, more rapid compilation and publication of data, and assurance of continued collections, especially those providing detailed occupation or program categories, e.g. upper division enrollment to the National Center for Education Statistics.

b. Survey of Earned Doctorates (NRC 1)

Each year (since 1957-58) the Commission on Human Resources, National Research Council, operating through the graduate deans of the various institutions, collects by questionnaire information on each person receiving an earned doctorate in any field. The survey, which achieves over 99% coverage, collects the following information for each awardee: name, race, sex, age, citizenship, high school and college education (year and location of school, field, and title of dissertation), source of financial support in graduate school, immediate post-award plans (fellowship, employment; type of employer) and so forth. Each year a few ad hoc questions are inserted such as on marital status and dependents.

This information is maintained in a computerized file so that summarizations of each year or a number of years data can be obtained. (The Commission maintains a more limited set of records on all doctorates awarded in all fields by U.S. institutions from 1920-1958). The survey is supported by the National Science Foundation, National Endowment for Arts and Humanities, U.S. Office of Education, and the National Institutes of Health. This source also provides annual cohorts of persons with doctorates for the so-called biennial Doctorate Roster Survey (NRC 2). No information is provided on energy-related activities except for such designation under an agency fellowship program and for some selected degree specialties, such as nuclear engineering and fuel technology, or petroleum engineering. The biennial Doctorate Roster Survey does of course identify those with significant work in energy and fuel programs. See section of this chapter on "Employment and Characteristics" (part B 1.).

Recommendation: That DOE indicate to and persuade the National Research

Council to add additional doctorate specialties relevant to energy activities and to collect information on the specific Federal source of support (e.g. DOE, NSF, NIH) for those involved as graduate assistants before award of the doctorate.

c. Nuclear Engineering Enrollments and Degrees (ERDA 3).

In 1975 the fifth annual survey of degrees and enrollments in nuclear engineering was conducted by Oak Ridge Associated Universities (ORAU) for ERDA. Each year the survey reaches all institutions which are known or thought to offer study in this area. Over the years the number of institutions has changed as new programs were identified or programs phased out (69 schools reported in 1975).

The survey collects data on enrollments and degrees, including undergraduate 3rd and 4th year, graduate enrollment for masters and doctorates, and degrees granted at the bachelor's, masters, and doctorate levels. In 1975, information was requested by specific curricula of nuclear engineering and on nuclear options in chemical, electrical, or mechanical engineering etc. and on women and minority students enrolled and graduated. The programs are also shown by institution.

Coverage is uncertain, but attempts are made to collect data from schools known or thought to be involved with nuclear education.

In 1975, a supplemental questionnaire was included which asked for data on placement or plans of degree recipients by type of position or job, e.g. academic, Government, GOCO's, or industrial employment.

d. Radiation Protection Enrollments and Degrees (ERDA 4)

In 1975, the fifth annual survey of enrollments and degrees in fields related to radiation protection was conducted by Oak Ridge Associated Universities (ORAU) for ERDA. Each year the survey was sent to institutions which are known or thought to offer educational programs in such areas as health physics, radiation health or safety, radiological health and similar programs. The numbers of institutions covered has changed over the 5 years as new programs were identified or programs phased out. In 1975, the survey covered 58 institutions.

Information is obtained on: 3rd and 4th year undergraduate enrollment, enrollment at masters and doctorate degree levels, and degree awards at bachelor's master's and doctor's degree levels. Data are classified by specific options such as health physics and by women and minority students. The programs are also shown by institution. Extent of coverage is uncertain. In 1975 a supplemental questionnaire was included which asked for data on placement or plans of degree recipients by type of position or job, e.g. academic, Government, GOCO's, or industrial employment.

e. Survey of Graduate Student Support and Post-Doctorals (NSF 13)

For a number of years the NSF has collected information on the types of support provided to graduate students and the number of post-doctoral and research associates engaged in doctorate-granting institutions. Data collected for Fall 1976 was for 1,489 masters and 6,289 doctorate level departments in science and engineering fields in 361 Ph.D granting institutions (including 105 medical schools) and 1,504 master's departments in 326 master's granting institutions. All Ph.D-granting schools are surveyed each year but presently a small sample of schools is contacted before the main survey to provide a preliminary indication of the direction and level of student enrollments.

The main survey collects for each Ph.D and master's department information for full-time students on: field of department, level of study, mechanism of support (fellowship, traineeship, research or teaching assistantship) source of support -- U.S. Government agency (Defense, NIH, other HEW, NSF, and all other), institutional support, foreign source, and self and family sources, etc.). Counts of part-time students and post-doctorals and research associates by department are also obtained.

Coverage on this survey for Ph.D. and master's degree granting schools is practically complete. No data on energy-related activities are obtained.

Recommendation: That DOE request NSF to identify the Department of Energy as a specific agency of Federal support on the questionnaire for this survey, so that data on DOE-supported students can be analyzed in the context of all graduate student support.

f. Survey of Graduate Enrollment (CGS 1)

For about 5 years the Council of Graduate Schools (CGS)/Graduate Record Examination Board (GREB) with aid of staff of the Educational Testing Service (ETS) has conducted an annual survey of enrollments of the member institutions of the Council of Graduate Schools. The Council membership consists of some 344 institutions who grant either the masters' or doctorate as the highest degree. The member institutions combined grant 99% of the earned doctorates and 85% of the masters' degrees.

The survey is conducted in two waves. The first forms sent out in September (to be returned by November) request data on the number of applications for graduate study, number of graduate assistants, graduate fellows, number of masters and doctorate degrees awarded, and total graduate enrollment (total and first time). Data are tabulated by size of school, type of control, and level of degree awarded. The second part of the survey is conducted by mail in the Spring following the first wave, with results coming in the Fall (showing information for the previous Fall). This second wave collects information by broad field (education, humanities, social science, physical sciences, engineering, and biological sciences) on the same items covered in the first phase and in addition on sex, ethnic group, and on teaching and research assistants.

g. Surveys of Enrollments and Degrees by Professional Societies and Trade Associations

A number of the professional societies in science and engineering areas conduct surveys of enrollments and degrees in the separate disciplines. Most of these cover known institutions offering options or curricula in disciplines relevant to the societies' interests. Also most of these surveys generally cover the same subjects: enrollments at the 3rd and 4th year of undergraduate study, enrollment (full-time and part-time) for masters and doctors' degrees, and degrees awarded at all three levels.

The most prominent ongoing surveys of this type include those by the Engineering Manpower Commission of the Engineers Joint Council (engineering and technology), American Chemical Society, American Institute of Physics, and the American Geological Institute. Other societies or associations which did or occasionally still conduct such studies include: the American Institute of Chemical Engineers, American Institute of Mining Engineers, Society of Geophysicists, the American Institute of Petroleum Geologists, the Society of Petroleum Engineers (of The American Institute of Mining Engineers) and the Air Conditioning and Refrigeration Institute. The information from the latter two organizations is more directly related to energy activities than that from others.

h. Junior Year Enrollment (ACE 1)

One of the surveys conducted by means of the Higher Education Panel (HEP) operated by the American Council on Education (ACE) for The National Science Foundation (NSF) has been a collection on enrollments in science and engineering fields at the junior year in colleges and universities. The survey, which has been conducted several times, provides information by field and type of institution control (public, private). It provides a quick look at the trend in enrollments which precede possible changes in degrees granted. However, the amount of data collected is limited; no data on energy are obtained.

i. Survey of College Freshmen (UCAL 1)

Each year a sample survey of freshmen in universities and colleges collects information on personal, professional, and education characteristics, career choice, planned undergraduate major, level of degree sought, and sources of financial support. These data offer a first look at the potential supply of college-trained personnel. The survey tends to focus on the process of education rather than on the potential products of the system. The sample of schools included in the universe has been subject to critical review in the past. However, meaningful changes have been made. All institutions included in the Higher Education General Information Surveys (HEGIS) are invited to participate. No data on energy-related activities are obtained.

j. Nuclear-related Technician Manpower (ERDA 6)

This survey of technicians in nuclear-related areas in twelve western States conducted by Oak Ridge Associated Universities (ORAU) for the Energy Research and Development Administration (ERDA) builds on two previous surveys covering southern States. Respondents included all of the government-owned, contractor-operated facilities in the ERDA system as well as other major industries, utilities and, educational institutions in western states. Among the information collected on training programs in the various facilities was data on enrollments and estimated graduations in selected technician specialties.

It appears that the survey successfully collected such data.

k. Industrial Training for Nuclear Power (ERDA 7)

Using a listing of industrial establishments published by the American Nuclear Society, the Manpower Assessment Office, Energy Research and Development Administration (ERDA) compiled an inventory of education, training, and work experience programs for nuclear power plant and facility personnel sponsored or conducted by industrial firms. The items included short-term (1 week), on-the-job programs, to 12 weeks or more formal courses in academic institutions for technician, craft, and related occupations.

The survey was not intended to be comprehensive. It does not cover all firms, even in the limited area of nuclear power.

l. Energy-Related Technology Programs in Community and Junior Colleges (ERDA 8)

In 1975, ERDA supported a survey conducted by Oak Ridge Associated Universities (ORAU) of energy-related programs in community and junior colleges. The survey had three general objectives:

1) to estimate the number of energy technical programs that colleges presently have and the number they are planning;

2) to estimate the degree and type of cooperation between colleges and energy industries, including major ERDA contractors;

3) to quantify the degree of college interest in attending a working conference to assess occupational needs in energy areas and initiate planning of needed programs.

The response to the survey, which was also promoted by the American Association of Community and Junior Colleges, was generally good and the general objectives met. Seven hundred seventy four responses were obtained.

Data were collected on the number of colleges and programs within them which were categorized in several of the major energy-related technologies, including petroleum, coal, nuclear, solar, geothermal, etc. Altogether 62 existing programs were identified in six energy areas and 132 programs were in various stages of planning. Some 18 colleges had existing programs. Thus, programs can be classified by energy area and technology, geographic region, etc. Apparently, industry is involved in a majority of programs in the colleges.

Recommendation: That DOE conduct a similar survey in the near future so as to provide input on the trends in numbers of energy-related courses, options, and curriculum being established in community and junior colleges.

m. Enrollments in Post-Secondary Occupational Training

At the present time no overall source of information on formal training of technicians, selected craftsmen, and related types of personnel exists. However, some selective information is provided which gives some indication of potential supply of technicians and craftsmen. These include:

1) the HEGIS survey on associate degrees and other formal awards below the baccalaureate and a similar survey of enrollments in organized occupational curricula (not conducted for several years);

2) a biennial survey conducted by the National Center of Education Statistics of enrollments in post-secondary schools not approved to the college level, including proprietary organizations;

3) information on numbers of persons engaged in and completing apprenticeship training (ETA 4) in "registered programs" (those registered with the Bureau of Apprenticeship and Training of the Department of Labor or affiliated State apprenticeship councils) -- large numbers are in programs not so registered;

4) numbers of persons in training under programs of the Comprehensive Employment and Training Act (CETA) (no national summaries are available);

5) selective information on persons approved or certified under Armed Forces training; and

6) information on training received by persons employed in technician and related occupations (NSF Post-censal survey, etc).

Information on specific training for occupations in energy RD&D is very weak.

Recommendation: That DOE join in efforts to persuade the National Center for Educational Statistics (using financial support, if necessary) to reinstate the surveys of enrollments in organized occupational curricula in higher education and to support more fully the collection and publication of survey data on such curricula in other post-secondary institutions.

It is also recommended that DOE initiate collection of information from technicians employed in energy activities (DOE-supported and other) on the sources of training received. This information would reveal which types of training should be surveyed to discover trends in potential energy technician supply.

n. Projections of Enrollments and Degrees and other Educational Measures

Several organizations and agencies have prepared and/or analyzed projections of college level enrollments and degrees in relation to employment requirements. These efforts, which are generally continued on a periodic basis, include those by: National Center for Education Statistics,* the National Science Foundation,** the Bureau of Labor Statistics,*** the Engineers Joint Council, the American Institute of Physics, and The National Board of Graduate Education. These organizations use differing methodologies, assumptions, and factors in these efforts, some of which are described in the discussion of methods of estimating degrees granted and completions programs in Chapter V.

3. Summary Evaluation of Existing Education and Training Data

There are several major established sources of information on the number of persons being trained in science, engineering, and related fields. The

* Department of Health, Education and Welfare, National Center for Education Statistics, Projections of Education Statistics to 1985-86, (NCES 77-402), 1977.

** National Science Foundation, Projections of Degrees and Enrollment in Science and Engineering Fields to 1985, (NSF 76-301), 1976.

*** Bureau of Labor Statistics, Occupational Projections and Training Data, Bulletin 1919, 1976.

Higher Education General Information Survey (HEGIS), the surveys of the National Science Foundation, National Academy of Sciences, the professional societies, and DOE provide a substantial amount of data on enrollments and degrees awarded in these areas and other measures of training activities.

As indicated above, our present structure or system, while giving considerable detail about fields of study in which degrees are granted, does not include (with a few exceptions) direct or specific education and/or training for jobs in energy research, development and demonstration activities. Rather, the supply of scientists and engineers now or to be engaged in energy RD&D work is part of the same overall pool as for all scientific and technical activities. The taxonomies of programs and instruction provided for surveys provide for a substantial amount of detail on fields of study. In some cases they are specific to energy RD&D such as nuclear, petroleum, or mining engineering, or geology. However, in most science and engineering fields the subject areas are too broad to indicate concern with energy matters per se.

The support of graduate students under a Federal agency's award for research and development or for direct training in a given program such as energy is an obvious stimulant to the potential supply of trained persons available for later employment in that area. However, it is apparent that adequate information does not exist at this time on the number of scientific and technical personnel being trained under DOE and other Federal agencies' direct training (fellowships and traineeships) programs or training under research and development contracts and grants for academic energy RD&D efforts. DOE does have a series of university training programs which provide for a limited number of persons in direct training programs. However, no central source of data exists on numbers and types of graduate assistants or other persons being supported under DOE awards to academic and related institutions (e.g., several of the National Laboratories employ graduate assistants). DOE's primary concern here is to know on whom its funds are being spent and how they compare with other students and those getting other Federal support as a basis for its policies on support of graduate students (either direct or under research grants and contract.)

One significant weakness of many of the current surveys of enrollment and degrees is the delay involved in making data available. This is particularly true of the HEGIS efforts, though many improvements have been made in recent years. It is likely that if data from these surveys could be made available sooner and provide specific data to certain clients, several other partial coverage surveys of enrollments and degrees could be dropped.

The present survey of graduate student support conducted by The National Science Foundation does not provide for indication of support of students by DOE or previous energy agencies. The survey does provide excellent information on the general subject of graduate student support.

The two surveys conducted by Oak Ridge Associated Universities of enrollments and degrees in radiation protection and nuclear engineering do not of course cover all specialties related to energy-related activities. They appear to cover the selected relevant fields most adequately. The survey conducted under sponsorship of ERDA on technicians is a good source but limited to nuclear and related areas.

4. Further Initiatives for Improvement and Development of Data Sources

The established surveys of education and training of scientific and technical personnel provide a broad base of information useful to the analysis of the supply of energy R&D manpower. Most of these surveys should be continued and in a number of instances expanded and improved. Improvement of some of the data sources might make it possible to omit other surveys, which seem to be duplicative. In addition, there are several gaps or weaknesses which DOE might aid in closing. Revisions, amendments, and adaptations of existing data sources have been indicated above. The following are the recommended new data collections:

a. Perhaps the single most important change or improvement to initiate is the collection of information on the numbers of graduate students, research associates, post-doctorals, and faculty engaged on all DOE supported activities carried out by academic and related (National Laboratories, etc.) institutions. Furthermore, it would aid consideration of DOE's policies on student support if the agency had information on those it supports in the context of the total graduate student body in science and engineering and the support programs of other agencies.

The numbers of persons directly supported by the university programs unit in DOE fellowships, traineeships and faculty training is very small compared to the number supported under research grants and contracts in educational institutions. Support of graduate students under these latter awards is a very obvious stimulant to additions to the energy R&D manpower pool. This is particularly true of those who specialized (through dissertation work) on specific energy areas. In addition, those research assistants, post-doctorates and faculty engaged under these grants and contracts may be directed into energy activities over the long term, thus adding to the manpower pool outside universities and colleges.

DOE should take steps immediately to establish a reporting system which will provide data on numbers, fields, man-years and other characteristics of all persons engaged in DOE supported direct and research training, and in related academic research, e.g. fellowships, traineeships, research assistants, post-doctorals and faculty. The system should cover all relevant institutions of higher education, related National Laboratories, and similar organizations under DOE support.

b. Several improvements are suggested in the area of information on the training of persons to less than the baccalaureate level. First, it appears that the reintroduction of collections of data on enrollments in organized occupational curricula (including energy-related revisions in the instructional taxonomy) would be useful. The National Center for Education Statistics has the statutory responsibilities to provide an improved data system on vocational and related education and it appears such data would be useful for these purposes.

A second suggestion in this area is for DOE to determine the types, levels, and sources of training received by employed energy technicians through occasional surveys (every 5 years or so) of such personnel, their supervisors, and employers. Then selected surveys of such sources of training could be undertaken, including information on content, facilities, and type of instruction involved.

D. SOURCES ON EXPENDITURES AND OBLIGATIONS

1. Introduction

Dollars, whether expressed as appropriations, obligations, costs, or expenditures, are the basic means of allocation for research and development (R&D) activities. These allocations characterize the purpose, nature, and extent of such activities and consequently determine the resources -- manpower, materials, machinery, plant, etc. -- needed to conduct them. Information on R&D spending is required in a manpower information system for at least two primary reasons: (a) R&D dollars are a specific, primary measure (similar to direct manpower data) which policy- and decision-makers use to plan, budget, and carry out specific activities: and (b) ratios of R&D spending to R&D manpower can be used to estimate or derive either of the two components, past, present and future. It is in this latter sense important to establish, as consistently as possible, common or compatible definitions, classifications, and taxonomies for both measures of R&D activities -- manpower and dollars. This isn't to say that in all types of measures the same detail of categorization is required for the two -- only that convertibility and comparability be possible.

The primary source of information on expenditures for energy research and development as well as R&D covering all programs, fields, and sectors, is the National Science Foundation. Beginning in the early 1950's NSF has established a coordinated, comprehensive series of data collections on research and development (funds and manpower), which covers all sectors of the national economy. (See chapter II for definitions used in the NSF surveys of R&D.)

However, information on R&D spending for energy is more limited. For many years the collection of information on Federal obligations for R&D by NSF (NSF 1) has included detail by agency, such as the Department of Defense (DOD) or the National Aeronautics and Space Administration (NASA). The R&D obligations of these agencies served as the measure of funds related to "defense" or "space" R&D. However, a significant portion of R&D dollars allocated to the DOD or to NASA was not spent for defense and space respectively. Also, other Federal agencies allocated some R&D funds to these activities.

In more recent years NSF has initiated the compilation of information on research and development activities specifically associated with selected national programs such as on energy and environment. Thus, for Federal agencies, the NSF in 1969 began an annual series on the allocation of Federal expenditures and obligations to various national programs and activities. NSF has produced annual reports on Federal R&D funding by "function" (a designation for national programs) (NSF 2.) In the latest compilation (Fiscal Year 1978) NSF reports on 15 major functional areas (and many detailed sub-functions within) including "energy development and conversion".

NSF also has initiated collection of data directly from private industrial concerns on R&D spending for the separate categories of "energy" and "pollution abatement" (NSF 4.) In addition, NSF has conducted a one time survey of current and prospective funding and manpower related to energy R&D activities in Federal intramural installations (NSF 3.)

In addition to the NSF series of studies and surveys of R&D spending and manpower several other organizations have collected information on both national totals and in a few cases on energy R&D. These include special compilations made of Federal agency budgets on several special analytical topics such as research and development, education, defense, energy, etc. by the Office of Management and Budget (OMB). The OMB compilation (Special Analysis P) is based primarily on NSF definitions and practices, but some differences in the interpretation of agency programs lead to different R&D spending totals. The Federal Trade Commission (FTC) and the Securities Exchange Commission (SEC) make periodic collections of data on R&D by selected industries. However, the FTC data are not complete and SEC does not publish its collected information.

Collections of information on industrial spending on research and development are also made by publishers of general and trade periodicals, such as McGraw-Hill, Industrial Research, Chemical and Engineering News, and Business Week, and other organizations such as Battelle Memorial Institute and the Pharmaceutical Manufacturers Association. These collections generally use NSF definitions and practices; however, each of them restricts itself to an industry or industry group or a particular segment of the economy. Furthermore, the collections usually are restricted to the industrial sector. At least one of these surveys (made by McGraw-Hill) collects data on energy R&D at periodic intervals.

Thus, the series of studies and surveys conducted by the National Science Foundation are the cornerstone and primary source of information on funding of R&D programs -- both national totals and energy.

2. Major Statistical Sources of Data on R&D Spending

Following are short descriptions of the major NSF and other surveys of RD&D expenditures and obligations currently programmed, including general content, methodology, and relevance to information on energy RD&D. Fuller descriptions of these surveys and studies is contained in Appendix B.

a. Federal Funds for Research, Development, and Other Scientific Activities (NSF 1.)

This annual collection of data from Federal agencies is a practically complete coverage of Federal spending for R&D. Data for three fiscal years are obtained each year: by performer, (industry, university, intramural unit, etc.), field of science, character of work (basic and applied research, development, but not on demonstration), and on R&D plant. No separate data are reported on energy R&D except for the designation of DOE activities, per se. The survey has been conducted for 25 years. This survey is supplemented by occasional reporting in broad detail on geographic distribution of R&D funds from Federal agencies (the last one was done in 1965), and annual analyses of Federal R&D funding by function and Federal support to universities, colleges and non-profit organizations (see below). Data on Federal R&D manpower are not collected through these surveys.

The definitions used for development and R&D plant can lead to some confusion with respect to funding of demonstration activities -- no specific description of demonstration is given. Also at present this survey classifies research and development in information sciences, documentation, and in information systems and practices as scientific and technical information rather than as research and development per se. Further, R&D in social science fields includes some research in law and education.

It also should be noted in connection with this survey, as well as the survey of Federal energy R&D in intramural laboratories and FFRDC's (NSF 3), and similar surveys in other sectors, that the list of FFRDC's established by NSF in cooperation with AEC and ERDA is not the same as ERDA's list of GOCO's for R&D. Most relevant facilities are on both lists, but selected sites on one list are not included on the other.

Recommendations: That DOE work with NSF to establish a definition of demonstration activities for reporting of Federal R&D funds and to clarify the definition of development and R&D plant in this regard. This definition should be consistent with that for such activities in all sectors (see part D4 below).

DOE should also encourage NSF to clearly indicate the inclusion of R&D in information sciences, documentation, etc. as a part of general R&D activities. Further, DOE should request NSF to consider the transfer of R&D in law and education into a category separate from the social sciences.

Finally, it is recommended that DOE cooperate with NSF in establishing criteria for, as well as an actual list of, R&D centers which though owned by the Government are operated by non-Federal organizations.

b. Analysis of Federal R&D Funding by Function (NSF 2.)

Since 1969, NSF has provided an analysis of Federal R&D funding by separate national programs or "function". This categorization of funds into 15 major functional areas and twice as many subfunctions within the major breaks, is prepared by NSF staff on the basis of detailed agency budgets and staff contacts. Function data are additive to 100 percent with no overlap of programs. Each functional area, including one on "energy development and conversion", is detailed by agency (including Bureaus and similar units or programs). As in the case of Federal Funds for R&D (above -- NSF 1), data for recent past years are revised with each new year's budget submittal. Details on the category of energy development and conversion include: nuclear; fossil, solar geothermal, and advanced energy systems; conservation; and other. Where enough specification is available, NSF staff has tried to include programs in other functional areas with energy, such as energy conservation R&D in the Department of Transportation. Here again no manpower data are available.

Recommendations: That DOE request NSF to provide further specifications, definitions, or explanations regarding the classification of R&D by function. The present method used -- by staff judgment and estimate -- is probably more reliable, consistent, and efficient than direct delineation by each agency. However, users of these functional data do not know of the specific criteria or bases of decisions on functional classifications, for example on fringe areas of the various categories.

c. Federal Support to Universities, College and Non-profit Organizations (NSF 7.)

Each year the NSF is required to report to the president and the Congress on the "total amount of money for scientific research, including money allocated for the construction of the facilities wherein such research is conducted, received by each educational institution and appropriate non-profit organization in the United States, by grant or contract, or other arrangement from agencies of the Federal Government ...". Therefore, NSF obtains from various Federal agencies information on funds provided various educational and non-profit institutions. Separate data are provided on Federally Funded Research and Development Centers (FFRDC's) administered by universities, non-profit research institutes, and other non-profit organizations. Information is gathered from about 14 agencies which account for over 95 percent of all Federal funds obligated to the universities and non-profit organizations. This information includes data on funding for R&D; for R&D plant; on facilities and equipment for instruction in science and engineering; on fellowships, traineeships, and training grants; on general support for science (e.g. institutional grants); on support for other scientific activities; and on support for non-science activities. Data are categorized by type of activity, agency, geographic location, and field of science; separate institutional data are available.

Specific detail on funds provided for energy-related activities (in R&D or otherwise) is not requested. However, the agency detail shows funds obligated by DOE (the primary funding agency for energy R&D funds).

d. Federal Intramural Performance of Energy R&D: Funds and Manpower (NSF 3.)

A single time survey was conducted in 1974 to collect further information on energy R&D identified through the annual Federal Funds for R&D survey (item a above). (See also section B, part 1a of this chapter). Each agency so identified was asked to provide for each intramural R&D installation and each of its Federally-Funded Research and Development Centers (FFRDC's) data on funding of energy projects and on manpower engaged for FY 1975 on an actual basis and projected for FY 1977 and FY 1979. Data were classified by R&D operating obligations, R&D plant obligations, and numbers of scientists, engineers, and technicians and these factors by individual program area -- conservation, oil, gas, nuclear fission and fusion, solar, etc. Agencies were asked to summarize the installation level data by reporting on an agency subdivision (Bureau, etc.) basis.

The coverage of the survey was nearly complete (compared to funds classified as energy-related in the annual report on Analysis of Federal R&D funding by Function). However, NSF has no present plans to continue this survey.

Recommendations: That DOE discuss with NSF the possibility of conducting another such survey. NSF may or may not have plans to do so (NSF would not so state in response to an inquiry). However, in view of the recommendation made later in part 4 of this section for an overall intramural survey in DOE, the plans of each of these agencies should be made clear.

e. Expenditures for Scientific Activities at Universities and Colleges (NSF 6.)

Each year NSF conducts a survey of research and development and related activities at the nation's universities and colleges. Formerly conducted as a single two-part survey of R&D funds and of science and engineering manpower, the surveys are now conducted separately. The companion survey on manpower is described under Section B, Part 1. The funding survey is directed at some 540 academic institutions and 22 related FFRDC's (1975 survey). These institutions include all awarding graduate degrees in the sciences or engineering and all other universities and colleges with over $50,000 in R&D expenditures. It is estimated that this results in coverage of over 99 percent of all academic R&D spending. Data are collected on current R&D expenditures (separately

182

budgeted), which can be categorized by source of funds (Federal, State, government, industry, institution's own funds, etc.), character of work (basic, applied, development), field of science, institutional control, level of degrees granted, and geographic location. Information is also gathered on capital expenditures for research, development and instruction and on current expenditures for instruction and departmental research in graduate-degree-granting institutions. Similar data are provided for both the institutions and for FFRDC's.

Response to the survey has been excellent; only eleven institutions failed to provide data for Fiscal Year 1975; imputations for these schools were made by NSF staff. Neither separate definitions nor data on demonstration activities are provided. Similarly no information on spending in energy-related programs is obtained. (See also description of companion source under R&D employment.)

Recommendation: That DOE initiate an effort to measure the magnitude and characteristics of energy RD&D conducted by the nation's universities and colleges and related organizations (FFRDC's, National Laboratories, etc.). As indicated later in part 4 of this sector, a recommendation is made for surveys of all activities supported by the DOE, including those carried out under grant or contract in universities and colleges.

Therefore, an alternative or choice of surveys or data collections should be made -- i.e., to cover the academic and related sectors for energy RD&D separately or to include that section as a part of the project to cover all DOE activities. More will be said about these choices later.

f. Research and Development in Industry (NSF 4.)

Annually, the Bureau of the Census, under support and sponsorship of the NSF, surveys private industrial companies regarding research and development activities. All told, twenty surveys of industrial firms have been conducted since 1953. A sample of industrial companies is chosen representing all manufacturing industries and those non-manufacturing industries known to engage in research and development.

Data are collected on costs of research and development activities performed: by major source of funds; by major type of expense (wages, material, etc.); fields of basic research (chemistry, engineering, physics, etc.); product group of applied research and development; location (State); and by two functional categories with some detail -- energy R&D and pollution abatement R&D. The survey also obtains information on man-years of R&D scientists and engineers (but not technicians), by Federal and company support, as well as data on company sales and total employment. Energy R&D data are detailed by major source (nuclear, oil, gas, coal, geothermal, solar, etc.). (See also section B, part 1a iii of this chapter).

The industry R&D survey, unlike other NSF sectoral surveys, exludes R&D in psychology and the social sciences. Similarly and perhaps more importantly for this sector, certain activities are excluded, which may be related to energy demonstration programs: market research, economic research, trouble shooting in connection with breakdowns in full-scale production, and "aid furnished to develop -- and to promote or demonstrate new products or processes, including the cost of material furnished for trial or demonstration". No separate definition of energy demonstration is furnished to respondents. Thus, it is unclear and perhaps highly probable that some of the energy demonstration activities funded by DOE may be excluded from the industry research and development survey.

Recommendation: That DOE work with the National Science Foundation to change and improve the concepts and definitions of R&D activities undertaken in the industrial sector. First, the separate divisions of activity in the

R&D spectrum should be more clearly stated so as to delineate "demonstration activities". These are carried out primarily in the industrial sector and are primarily funded by the DOE. They are planned by DOE to be a part of a broad R&D process and not to extend to the ultimate commercial stage. In general, "operational" rather than "capital" funds are used by DOE for these activities.

Second, DOE should represent to NSF that the current exclusion of R&D in psychology and the social sciences (particularly the latter) omits certain R&D of relevance to energy programs. The inclusion for example of certain R&D in the economic area is directly relevant to demonstration projects.

Consideration will have to be given to the relationship of the proposed master survey of DOE supported activities in the various sectors to this NSF survey of industrial firms.

g. R&D Activities of Independent Non-profit Institutions (NSF 8.)

Periodically (every 3-4 years) NSF has conducted surveys of various types of independent non-profit organizations. These include research institutes, voluntary hospitals, Federally Funded Research and Development Centers administered by non-profit organizations, professional and technical societies, private foundations, science exhibitors, and trade associations.

The latest survey covered 1973 activities and collected information on current expenditures for all activities, research and development programs, and on number of scientists, engineers, and technicians. (See section B, part 1a xii of this chapter). Research and development data were obtained by source of funds (Federal government, industry, own funds, etc.) and by field of science. No information was obtained on involvement in energy research and development activities.

This sector of R&D performance is a relatively small but important one. One limitation of the NSF survey is the difficulty of obtaining master lists from which survey respondents can be selected. No single directory exists covering all types of non-profit organizations; therefore NSF has developed lists from previous surveys, and specialized directories. Also there are complex relationships which exist among non-profit institutions and with organizations outside this sector, e.g. educational institutions.

Recommendation: That DOE request that NSF consider the conduct of a survey covering R&D programs of the various types of non-profit organizations. Specifically, NSF should provide for coverage of energy RD&D activities in these organizations.

h. R&D Expenditures by State and Local Governments (NSF 5 and 17.)

Periodically (every 3-4 years) the National Science Foundation has collected information on the R&D activities of State Governments. The last such survey covered fiscal years 1972 and 1973. It was carried out with the cooperation of the Bureau of the Census. The universe was the agencies of all 50 States, excluding state universities, colleges and their affiliated medical schools, hospitals, agricultural experiment stations, and research centers. The agencies were identified from previous surveys and other sources. A list of agencies for each state was assembled and reviewed by State budget offices (not all such officers responded). Then questionnaires were mailed to agencies in all states. A response rate of about 98 percent was achieved after screening for mergers, phase-outs, etc. Some 519 agencies of 1,276 responding reported R&D expenditure.

Data collected included R&D expenditures by function (health, natural resources, transportation and communications); field of science (chemistry, physics, etc.); and performer (state agency, universities, etc.), source of funds, and character of work (basic and applied research, development) and on full-time equivalent counts of scientists, engineers, and technicians engaged in research and development work by field and by function. (See section B, part 1a xii of this chapter). Unfortunately, the functional data did not include a separate category on energy activities (in 1972 this subject had not achieved enough recognition to be listed).

NSF also conducted two surveys of R&D in local government agencies, one covering fiscal years 1966 and 1967 and the other 1968 and 1969. The latter survey collected information by individual R&D project on field of science; source of funds (Federal, State, local, etc.); expenditures for R&D plant; manyears of R&D employment separately for scientists, technicians, and other personnel; character of R&D work (basic and applied research, development); and amount of R&D work performed by other organizations using local government funds.

NSF is currently planning surveys of both state and local government agencies to be conducted by the Bureau of the Census and covering Fiscal Year 1977.

Recommendation: That DOE make known to NSF needs for information for energy RD&D activities in the Fiscal Year 1977 surveys of programs in State and local government agencies. These needs include clarification of the details of energy RD&D.

i. National Patterns of R&D Resources: Funds and Manpower (NSF 9.)

This is an annual compilation made by the NSF of all data from the Foundation series of surveys of research and development activities. This is the existing standard national source of data on this subject. Coverage, timing, and representativeness vary by sector (see above surveys). Each annual report contains information on trends in R&D funding and manpower since data were first collected by NSF (the latest report covers 1953 to 1977).

Though certain surveys are not conducted annually -- non-profit institutions and State and local governments -- NSF provides interpolated estimates based on long-run trends. Each National Pattern report provides overall summary data on expenditures and manpower as well as selected details and breakdowns provided by individual sector surveys.

j. Inventory of Energy Research and Development (ORNL 1.)

Oak Ridge National Laboratory (ORNL-Tennessee) has conducted three periodic surveys (an additional one is now underway covering 1976 through 1978) of current energy-related R&D. These three surveys were undertaken under sponsorship of NSF and ERDA. The latest survey data, which cover three years (1973-75), expands and updates the two earlier inventories of 1972 and 1974. The subcommittee on Energy RD&D of the House Committee on Science and Technology has sponsored these inventories and published their results.

Respondents to the survey are selected by the ORNL staff from listings of previous inventory surveys and industrial firms, trade associations, universities, non-profit institutions, and government agencies. These respondents are requested to reply to questionnaire on a project-by-project basis on their energy-related R&D programs. The respondents are asked to provide information describing the organization, as well as data by project on the numbers of scientists and engineers involved (technicians not included), the research sponsor, the yearly R&D expenditures by year, the proportion of the R&D which is basic or applied research or development, a description of the R&D project and the fields and types of energy concerned (coal, nuclear, electric power generation, and a good many detailed categories). (See section B, part 1a of this chapter).

ORNL estimates that the inventory survey covered 80-85 percent of all energy-related R&D performed in the U.S. in 1973. The 1973-75 survey reported on about 6,500 projects totaling some $2.5 billion. However, though comparisons with other sources of data were made by ORNL it is not known how complete or representative the survey was. Instructions as to cut-off and the lack of an actual universe of possible respondents leaves coverage in doubt. The proposed survey covering current years will use a sampling approach which may even lessen its representativeness. Further, it is not known to what extent "demonstration" activities will be covered. It is not clear also to what extent various DOE needs for information were considered in the design of the inventory surveys.

Recommendation: That DOE in future coordinate various needs within the Department, as well as with other agencies collecting and analyzing for information on energy RD&D programs. Inventory activities might well be coordinated with the Directory of Establishments Conducting Energy R&D recommended in section B 1, part a i of this chapter.

3. Summary and Evaluation of Current Information on R&D Spending

The National Science Foundation has established and maintains a comprehensive, integrated series of surveys of funding of Research and Development activities. These surveys are carried out in the several major sectors of the national economy: Federal Government, State governments, private industrial concerns, universities and colleges, and miscellaneous independent nonprofit organizations. Federally-funded Research and Development Centers (FFRDC's) administered by various non-federal organizations are also covered. Most R&D surveys are made on an annual or biennial basis: the Federal, industry, and universities sectors are surveyed annually. Generally speaking, a core set of common definitions and questions are used across the sectors, with additional questions and detail and slight adjustments in definitions for certain sectors. For example, a slightly different definition for basic research is provided for the industry sector compared to that for universities. (See chapter II, section B).

Though NSF has a comprehensive survey series on R&D funding, the program has several gaps, inconsistencies, and weaknesses. These problems affect directly the adequacy of an ongoing or improved system of data collection and analysis of energy RD&D activities. Among the problem areas relevant to information on national R&D total are the following:

a. Industrial Sector

Presently the definitions used for this annual survey exclude R&D in psychology and the social sciences. Further, the definition also excludes certain activities which may be related to the advanced development and demonstration programs funded by DOE and other Government agencies. Thus, at best it is unclear whether certain activities (mainly demonstration) are being included under "development" in the industry survey. Furthermore, it may be that some of these activities are being excluded completely.

b. State and Local Governments

Though NSF has surveys in planning for Fiscal Year 1977 of both State and local R&D activities, a considerable lapse in time has occurred since previous surveys in these areas -- 1968-69 for local governments and 1973 for State. It is hoped that in the future NSF will be able to conduct other surveys in these areas without such long time gaps.

Furthermore, it is most important that a measure of energy RD&D activities be made for these two segments of the economy.

c. Independent Non-Profit Institutions

These organizations also have not been surveyed since 1973. Here again, though the entire segment constitutes a relatively small proportion of all R&D, several types of organization have significant programs. A decrease in the length of time between surveys is indicated. More importantly no measure of energy RD&D in this sector has been made.

d. Federal Government Sector

Information on the functional categories of Federal obligations for R&D (energy, space, defense, etc.) is not provided directly by the agencies. Rather these data are derived by NSF staff from detailed budgets ~~and consultations~~ with NSF staff. No specific criteria are published to delineate the staff choice of major functions and subfunctions (particularly fringe areas between categories). Over the years different staff estimates could be obtained based on subjective decisions as to program content.

It would also appear that the definitions used for development and R&D plant could lead to some confusion -- particular with respect to funding of large-scale demonstration plants. A specific description of demonstration funding is lacking.

Presently research and development in information sciences; documentation; and information systems, techniques, and practices are included under scientific and technical information rather than under R&D in general. At the present time R&D in social science fields includes research in law and education.

e. University Sector

The primary weakness of this source is the lack of a measure of energy RD&D activities. This will admittedly be a difficult task to remedy. Generally, academic research and development is categorized in terms of disciplines, subject matter areas, or departments and other units. Furthermore, most (70 percent) of it is classified as basic research.

f. Energy-related RD&D

As indicated above, information on energy RD&D activities is presently collected only in the industry and Federal Government sector by the National Science Foundation. The energy R&D Project Inventory undertaken by Oak Ridge National Laboratory (ORNL) does cover such work in the university and non-profit areas; however, this is not the same type of data collection as is made by the NSF. One major weakness of the ORNL survey is that it is not based on a known universe listing or sample in the sectors and it is not tied in to all non-energy R&D or to national totals.

One significant area in need of clarification and improvement is the specific delineation of RD&D in energy areas. The present definitions of the phases of R&D leave unclear the specification or inclusion of the demonstration programs which generally involve larger expenditures than other parts of R&D efforts. Such projects are of considerable interest to DOE in tracking the application of R&D fundings to commercial use being funded primarily by DOE. The problem of definitions for demonstrations holds true across all sector surveys, but it is particularly applicable in the industrial sector. Another subject area of concern is the conduct of research in basic science areas or basic research per se. It is often not clear as to the inclusion or exclusion of selected areas under energy RD&D. For example, it would appear that ERDA did not classify certain of its programs as energy RD&D. These include high energy physics, naval reactor development, space nuclear systems, operational safety, weapons, and nuclear explosives R&D. Nor were all classified as R&D (e.g., U-235 production).

Another disparity in present reporting of energy RD&D is that detail of data collected by energy source is not quite the same in the industry and Federal surveys. Also no survey (except for internal DOE reporting and, to some extent, the ORNL Inventory) provides information by type of energy technology or by the varieties of programs included under the broad categories of fossil, solar, nuclear, etc. Admittedly, every detailed category cannot be used for data collection, but there is a substantial difference in resource and manpower allocations by the various categories which would be buried under a broad category such as coal, oil, or solar.

Finally, it would appear that there is a need for clarification of the differences in listing of FFRDC's for DOE and DOE's list of GOCO's.

4. Further Initiatives for Improvement and Development of Data Sources on R&D Funding

As indicated above, the series of studies and surveys undertaken by the National Science Foundation has several gaps and weaknesses which should be corrected or improved, as indicated under each source described.

These changes should be made so that a more specific program of information on energy RD&D funding and manpower can be established against an improved base of national data on all R&D funding and manpower.

It is important here to establish again the rationale for obtaining and making available information on R&D funding. Basically, data on energy RD&D spending and obligations are required in a manpower information system for two primary reasons: first, it is a specific resource or measure, complementary to direct manpower data, which policy- and decision-makers use to plan, allocate, and carry out specific R&D activities, that is, the size and shape of R&D programs are basically described in this fashion; and second, ratios of R&D dollars spent to employed manpower can be used to estimate or derive manpower data from expenditure data, both past and future. Furthermore, such measures of energy R&D -- funding and manpower -- establish its magnitude against the backdrop of total spending for all types of R&D, total government spending for all activities, the total Federal government spending for all R&D, as well as against total manpower measures.

Whatever corrections or improvements are to be made in data collections on RD&D, it is recommended that they be made as much as possible in the established collections -- particularly those of the National Science Foundation. In other words, it is recommended that competing systems or data collections not be established. Therefore, DOE will have to use any means at its disposal -- financial support or missionary efforts -- directed at NSF and/or data users; pressures created by the Office of Management and Budget or other Executive Offices; or other devices -- to extend and improve the collections primarily made by others. Of course there will be some needs not applicable to "established" collections. There will also be cases where persuasion will not work. Thus, DOE will have to meet these needs with other means at their disposal including their own survey efforts. One example is the set of surveys proposed for coverage of intramural and GOCO activities of the department. Revisions, amendments, and adaptations of existing data sources have been indicated above. Following are recommended new data collections or policies.

a. Data on DOE RD&D Activities

The most important action indicated for DOE in the area of R&D funding is to initiate collection of data on all DOE-conducted or supported activities. Necessary to the establishment of sound data sources in the remainder of the economy is the clear indication that the specific impact of the DOE programs is being measured.

As indicated previously several basic conditions prescribe such an effort. Even before the organization of the Department of Energy, ERDA funds supported projects that were not energy-related (space nuclear, high-energy physics, etc.) and/or were not R&D (U-235 production, weapons materials, etc.). Further, the addition of activities of the Federal Energy Administration, Federal Power Commission, and other agencies have added programs which, while related, either are not energy activities or are not R&D.

It is plain that energy programs and the related RD&D activities will be carried out within a framework that may include other related activities serve broader purposes. The needs for information for all of these programs will in most cases be similar and the means for generating the information organizationally integrated. It seems prudent to anticipate the broader information needs by planning at the start for a comprehensive system.

Therefore, it is recommended that without delay DOE proceed to establish a system which would furnish at regular intervals (e.g. annually) specific fiscal information on all DOE-related activities. This would be the basic data source on RD&D and related programs to which other established surveys of research and development -- energy-related and other -- could be joined. The data system for DOE itself should cover the following segments: all DOE intramural programs in headquarters, field offices, Energy Research Centers and the like; all programs conducted by Government-Owned, Contractor-Operated facilities (GOCO's) including National and other laboratories, test sites, field stations and similar units; and all DOE contract and grants projects conducted by industrial firms, universities and colleges, non-profit organizations, other Federal agencies and state and local agencies.

Three basic types of data elements are suggested for inclusion in the DOE data system -- RD&D and other funding, manpower, and training data. A starting point for the delineation of program categories is the established "Budget and Reporting Classifications" promulgated by the Office of the Comptroller of DOE (see Appendix). This taxonomy provides for detailed categorization by several approaches including energy source (fossil, solar, nuclear), energy stage (exploration, production, and RD&D), and by technology (coal gasification, solar heating and cooling). At present the system does not allow for a cross-classification of these approaches, but more importantly the system does not provide for classification of all programs as RD&D or not, much less by whether they are either research, development or demonstration. Thus, a separate cross-classification system needs to be set forth so that DOE programs can be separated into energy-related, energy RD&D, or all other.

Various data elements concerning manpower engaged in RD&D programs and persons being supported under academic and related grants and contracts (graduate assistants, fellows, trainees, etc.) involving training have been described in other parts of this chapter or in terms of the taxonomies included in Chapter II or Appendix A. The following types of data elements for funding would be required: character of work (basic research, applied research, development, demonstration, and R&D plant and other); and program category (the various delineations of energy-related areas, other DOE programs such as weapons R&D or production). (Employment by occupation would be collected also, as recommended earlier in this chapter in the section on employment.)

This system concerning DOE projects (conducted or supported) is not a single survey or data collection. The master survey system should have at least the three parts mentioned above -- DOE intramural, GOCO's and related, and DOE grant and contract. And obviously, more detail should be requested on the first two segments including data needed for purposes other than manpower assessment (general contract reporting, EEO, etc.)

Much of the data needed for the manpower information system is the same or close to the data needed for the normal financial and operating review by DOE of its own employees' work and the work on its contracts. It is possible, therefore, that the information could be collected as part of the normal reporting system for contractors, thus eliminating duplication of reporting. But clear and workable arrangements would have to be made for assuring that the manpower information system has ready access to the data it needs.

Further, since the NSF surveys of R&D funding in the various sectors will continue, it will be necessary to coordinate the DOE master surveys with these NSF data collections, for example in the industry and education sectors.

Finally, as indicated in Chapter II, it will be necessary to coordinate the data collections so as achieve comparability and consistency among the general measures of manpower, training, and funding.

b. Surveys of RD&D on Energy Not Supported by DOE

A second recommendation for action indicated in the various sources above in this section is to provide for the collection of data on RD&D funding in the non-Federal sectors of the economy that is not supported by DOE. At present, except for the Inventory of Energy RD&D projects made by Oak Ridge National Laboratory (ORNL 1), measurements are taken only for the Federal and industry sectors.

i. It is recommended that some information on energy R&D expenditures be collected in all major sectors. It would appear that making such an addition to the surveys of independent non-profit organizations and state government would not be difficult. The need for more frequent surveys in these sectors was indicated above in sections 2g and 2h. However, it is recognized that data collection on energy RD&D activities in a universities and colleges survey would be more difficult. Generally, academic research and development is categorized in terms of disciplines, subject areas, departments, or other organizational units. A study should be undertaken (in cooperation with NSF) to identify problem areas connected with such data collection and to provide recommendations for their solution. Most of the R&D (90%) performed by universities and colleges is supported by other than institutional funds; two-thirds is supported by Federal funds alone. It is fair to say that each individual sponsor of R&D projects could inform the performer as to the approximate function under which to report them -- such as energy, environment, or defense -- even if the primary agency mission doesn't make this clear (e.g. NASA, DOE). The specific means by which universities and colleges would provide data on energy RD&D cannot be spelled out at this time. Since several of the National Laboratories supported by DOE are operated by universities or consortia of them (and in some cases integrated with them), DOE will have to decide on the best means of covering energy RD&D in these units -- inclusion in the general survey of GOCO's or in the NSF survey of universities, or otherwise.

ii. A second major area of improvement is to attempt to provide a greater degree of detail on energy R&D spending -- either by categories of technologies or by further detail under separate sources (fossil, solar, nuclear, etc.). At the present time this information can be provided on DOE funding. It is likely that similar reporting could be provided by other Federal agencies. In the major performing sectors, industry and educational institutions, this may be more difficult. However, a greater level of detail on spending is required in order to gain insight into the types of manpower utilized in energy RD&D programs. For example, under coal R&D, significant programs exist for liquefaction (high BTU, low BTU, and in-situ), advanced power systems (open and closed cycle gas turbines), direct combustion, advanced research and supporting technology, and magnetohydrodynamics. Significant differences in types and numbers of scientists and engineers are involved in these sub-programs.

For the data collections of RD&D not supported by DOE, it is very important that definitions of research and development and related activities be changed and improved so as to delineate and clarify the phases of R&D efforts. First, a decision has to be made as to the specifics of demonstration activities -- are they to be included in R&D and if so, on what basis? Second, it is evident that the process of R&D has been stretched in time and concept, so that the lines particularly between applied research and development and between development and the further steps toward production have become hazy and unclear. It is possible that several stages of development are required similar to those now being used by DOE, i.e., technology development, engineering development, and demonstration. Third, it would appear that the provision of specific examples of types of work carried on under each phase of R&D would help respondents. The above recommendations apply to both total R&D and to energy RD&D.

CHAPTER V

APPLICATION AND UTILIZATION OF THE ELEMENTS OF THE COMPREHENSIVE ENERGY MANPOWER INFORMATION SYSTEM FOR MANPOWER ASSESSMENT

The assessments needed by DOE on energy RD&D manpower include both appraisal of the present situation and identification of prospective manpower problems. This chapter will discuss the utilization of the elements of the system described in Chapter IV for both these purposes.

A. REPORTING ON THE PRESENT SITUATION

1. Some Questions DOE Needs Answers To

In the first chapter, we cited illustrative questions that a system user would be likely to ask and the kinds of information that would be needed to answer them. Let us briefly recapitulate the questions relating to the current employment situation as a basis for describing how specific components of the information system can be applied to resolving them:

a. What is the volume of STP manpower now engaged in energy RD&D? How are they deployed between energy technologies? Stages of RD&D? Occupations? Industries? To what extent and according to what pattern is manpower drawn from other occupations?

b. Are any energy RD&D programs now being hampered by personnel or manpower problems? What are the nature and causes of these problems, and what policy steps might be taken to deal with them?

c. In order to achieve the fullest and fairest utilization of manpower resources, are policies on equal employment being carried out in the staffing of DOE-supported RD&D programs?

In order to answer these questions, a variety of basic data sources have to be reviewed to establish the character and dimensions of currently available manpower supply, and still other data sources have to be examined to learn whether problems exist and what they are. The first step, estimating the numbers and characteristics of manpower engaged in or available for energy activities, should constitute a regular procedure with a periodic product once the information system has been established. The identification of problems involves a data watch on sensitive indicators, with follow-ups to confirm the signals given by these indicators and to learn more about the nature of the problems and potential remedies for them. The following sections describe the way in which data components can be used for these purposes.

2. Numbers and Characteristics of the Manpower Supply For Energy

a. STP Engaged in Energy RD&D

The annual surveys recommended in Chapter IV will provide the basis for estimating the numbers of scientific and technical employees currently engaged in RD&D by type of energy by the following steps:

i. The first segment will consist of those employed directly by DOE in its constituent agencies and intramural laboratories and in the GOCO's, data for which will be collected at least annually in a manner coordinated with respect to occupation and type of technology specifications. This segment will provide complete coverage of the STP employment in those establishments with which DOE is chiefly concerned. Since the specifications call for all STP employment in the designated occupations, those engaged in other than RD&D, and other than energy, will also be identified.

ii. STP employment data for other Federally-funded energy RD&D will be collected on reports from Federal agencies, contractors, and grantees involved. Separate reporting arrangements should solicit cooperation from the non-DOE Federal agencies affected, such as DOD, NSF, Agriculture, etc. An annual survey of Federal Government contractors and grantees engaged in energy RD&D will produce information on the STP employed on Government-funded projects. Occupations by type of energy will be among the elements reported. Together with the DOE reporting above, estimates of all STP employment on energy RD&D supported by Federal funds along with the amount of funds expended will be possible.

178

iii. Other segments to complete the employment estimates are the workers engaged in energy RD&D funded entirely from non-federal sources, especially in private industry, universities, non-profit institutions, State and local governments, etc.. Recourse to the Directory of establishments engaged in RD&D will provide a sample from which data on employment by occupation and type of energy technology can be derived.

As the system is conceived, the three part system discussed above will permit estimates of energy RD&D employment by type of energy and occupations with Federal and other RD&D funds separately identified.

b. Other STP Engaged in Energy Activities.

In addition to STP manpower engaged in energy RD&D, DOE must be cognizant of the manpower supply in similar occupations engaged in other energy activities. These latter include production, testing, teaching, etc., many of which require expertise closely related to RD&D. A certain amount of job transfer between these activities occurs continuously; assessment of RD&D manpower is incomplete without consideration of possible augmentation or subtraction through these related activities.

The periodic reporting of the DOE units and GOCO's noted above calls for all STP engaged in whatever activities so that the energy non-RD&D employment will be available for this segment. The National Sample of Scientists and Engineers (NSF 15), when fully operational with the expansion and modification proposed in Chapter IV, will provide national estimates of STP engaged in energy activities by categories on a biennial basis. By subtraction of the energy RD&D employment, a net energy employment estimate for non RD&D -- STP occupations remains.

c. STP Manpower in Other Activities

Although the principal interest of the DOE is expected to be in STP employment in energy activities as noted, some attention should also be given to the manpower supply in these occupations not engaged in energy. A part of this supply may become available for energy activities under certain conditions; for example, a research physicist undertaking fundamental research in magnetism, or a ceramics engineer attracted to geothermal fluids corrosion problems.

While the National Sample of Scientists and Engineers (NSF 15), when developed as proposed, will provide biennial manpower supply data for the principal STP occupations, other data sources are more immediately available. The BLS Occupational Employment Survey (BLS 2) is the principal source of occupational manpower estimates made periodically by that agency. The decennial Census of Population and the forthcoming quinquennial census beginning with 1985 should be kept in mind. Interim NSF estimates are useful for this purpose as are the manpower data of such professional societies as the Engineering Manpower Commission, the American Chemical Society, the American Institute of Physics, and others for selected occupations. Several of these sources provide estimates of unemployed STP as well as the employed.

d. Non-STP Occupations

The comprehensive energy manpower information system has largely been defined in terms of the professional STP occupations which are likely to cause staffing problems since they do not respond as quickly to changing labor market factors as do workers in occupations requiring shorter training periods. However, certain of the crafts, such as machinists, construction crafts, or pattern makers, and semi-skilled occupations, are examples of occupations which may become important concerns to DOE.

Manpower supply data for such occupations are less numerous and frequent. The decennial Census provides benchmark data, and periodic estimates by the BLS based upon employment surveys are available. The Bureau of Apprenticeship and Training in the Labor Department provides completion and enrollment data for apprenticeable occupations meeting Federal program standards (ETA 4). The addition of such occupations, when critical, to the DOE and GOCO periodic reporting system will provide a useful new element for assessing the manpower supply.

3. Assessing Problems in Staffing Energy RD&D Programs

The potential for manpower problems cannot be overlooked in the massive array of RD&D programs that DOE now has central responsibility for planning, initiating and supporting. The programs are varied, complex, large-scale, and often carefully sequenced in stages of differing activity. The programs also often change as unpromising leads are dropped and new initiatives developed to exploit openings made by other research or to meet changing national needs.

These programs require large numbers of highly specialized personnel, whose availability and qualifications are critical to the success of the programs' objectives. The number and kind of the personnel required are also subject to change according to changing program emphases.

DOE therefore has to be alert to the signs that may herald manpower problems that will hamper the conduct of RD&D programs, either delaying their outcomes or frustrating their looked-for success. To learn of these incipient problems, the relevant current indicators in the information system have to be regularly watched and analyzed. To be of use, the analyses should be regularly transmitted in comprehensible form to officials concerned with RD&D program planning through channels of communication established for this purpose.

The data watch on potential problem indicators should include the following areas:

a. Turnover and Employment Changes

Do rising turnover rates signal problems in some programs or facilities as compared with others? Are the causes reflected in other indicators, such as expanding employment in other activities or industries? Or do they reflect management or personnel problems for which other documentation should be sought?

The primary data source on turnover is Contractor Employment and Turnover (ERDA 2) which covers the approximately 60 GOCO facilities. Total separation and accessions are given, plus detail on quits and layoffs, with breakouts on all items for women and minorities. Inasmuch as quits and layoffs respond inversely to each other, according to changes in the labor market, it is important to identify which of these components accounts for the turnover changes. (Quits, as noted before, increase in a tight labor market, decrease in a loose one.) Analysis of the data should consider:

1) Changes in trend over time;
2) Disparities between different facilities or occupations at a given time; and
3) Sharp divergencies between internal DOE and other indicators (e.g. BLS 3) allowing for differences in coverage of these indicators.

While useful analysis can be made of Contractor Employment and Turnover data even with the present gross classifications of occupations, more meaningful analysis depends on the adoption of recommendations made in the previous chapter for a substantial expansion of the occupational detail reported in that survey.

The only other major "outside" indicator of turnover against which DOE experience can be compared is the BLS measure of Labor Turnover in Manufacturing and Mining (BLS 3). Because the BLS measure contains only industry identifications and no occupational identifications whatever, comparisons of the analogous universes can only be crude, the best approximation being that of energy-related industries identified by SIC in the BLS measure. The composition of GOCO and BLS employment coverage differs significantly, because a substantial proportion (about 40 percent) of all GOCO employment consists of scientists and engineers, and the factory employment covered by BLS has only a small proportion of such occupations.* Notwithstanding this limitation, the use of the BLS measure to establish a "background count" -- an estimate of tightness or looseness in the overall employment universe in energy industries -- can yield important clues as to the causes of turnover changes in various energy sectors in which DOE is interested.

Reference to employment indicators described in Chapter 4 can supplement the turnover data in documenting alternative employment demands (indicated by expanding or contracting employment) in related industries or occupations.

b. Salary Rates

Are disparities appearing in occupational salary rates that hamper hiring or retaining needed specialists?

Do the salary rates for all scientists and engineers engaged in R&D or in certain categories of facilities (as indicated by Battelle's National Survey of Compensation -- BATL 1) show significantly different trends from those in all GOCO establishments or selected laboratories? Can the background trends in salaries be confirmed in the other data sources described in Chapter 4? (What does the BLS-PATC survey (BLS 1) show for chemists and engineers, for example?)

*Professional and technical workers account for about 15 percent of all workers, and slightly more in manufacturing.

Are offering salaries in the Endicott (NWU 1) or College Placement (CPC 1), or professional society reports departing from entry rates for equivalent jobs in Government establishments? Are job offers in these "outside" indicators increasing rapidly or showing signs of remaining unfilled?

c. Want Ads

Is there evidence of a significant expansion or contraction in the overall demand for scientists and engineers that should be taken into account in DOE-guided personnel policies on recruitment, [illegible] promotion and prerequisites? The Deutsch, Shea and Evans "Engineer/Scientist Demand Index" (DSE 1) provides a confirming indicator of the level of recruitment activity as evidenced by the volume of want ads. Professional society journals carry notices of openings and applications and often summarize the state of their job markets. At least one organization -- The Scientific Manpower Commission -- reports monthly on supply and demand developments in all S&E manpower*

d. Unfilled Openings

To the evidence of unfilled openings shown in the internal reporting system of DOE, some further evidence on shortages in manpower can be found in public employment office reports on the volume and nature of unfilled openings or job orders. The U.S. Employment Service's files of unfilled openings or job orders show the occupations in demand by employers, salaries offered, and the areas where these jobs need to be filled. (These are shown in USES "Job-Flo" and "Occupations in Demand" reports, ETA 3.)

Like many indicators developed for operational needs that do not always coincide with the analyst's interest in the state of the job market, the available indicators are not always conclusive and need confirmation by other indicators, but by analysis of the relevant components in a system of information the market tendencies can be made clear.

*The Scientific Manpower Commission is a participating organization of the American Association for the Advancement of Science. While generally not an original source of data, it collates and publishes compendiums of data on S&E manpower (see SMC 1) and reports on supply/demand developments shown in other data sources in its monthly publication, <u>Scientific Engineering Technical Manpower Comments</u>.

e. Other Labor Market Indications of Difficulties in Hiring or Finding Jobs

An example of confirming evidence on difficulties in hiring is given by the Endicott (or Northwestern University) Survey report (NWU 1). This gives the number of jobs and the average salaries offered by employers to college and university graduates in typical graduate entry jobs. The survey also shows the actual hires made and the actual salaries paid compared to the offers made the previous year. This comparison of employers' expectations and their actual experience reflects to a fair degree the state of actual job market responses to employers' assessments of what those responses will be.

Additional confirming evidence should be sought in other indicators. The College Placement Council's reports parallel those of Endicott to some extent in what they seek to show about employment offers to new entrants, and they should be examined to judge the state of the job market. This involves comparison of CPC's Annual Survey of Job Offers to College Graduates (CPC 1) with those of previous years and similar examination of their Recruiting Activity Reports (CPC 2) to test employers' actual hires against their previous plans to hire. The Engineering Manpower Commission of the Engineers' Joint Council publishes additional evidence on the job market in its Survey of Placement of Engineering Graduates (EMC 2). These reports reveal gradations in the employment status of engineering graduates which reflect to a fair degree the strength of employer demand and the comparative success of graduates in getting hired. The relative position of STP supply in relation to demand is also indicated in the Applicant File of the Employment Service (ETA 1) which shows, by occupation, the volume of job seekers at Employment Service offices. Some of these applicants will be unemployed, others will be employed individuals seeking better jobs. Even though USES has been only a minor intermediary in the STP job market, changes in the small proportion of job seekers using the USES can be indicative of changes in the relative balance of supply and demand by revealing unusual difficulties either in hiring or getting hired.

Again, as in many other indicators, the experiences reflected in these reports are not always relevant to the situation in specific occupations, but they signal an alert to influences which may also affect the specific occupations and point to a need for systematic exploration of all other relevant indicators.

The "Manpower Intelligence Network" proposed in Chapter IV would add information that is current, flexible, and focused on energy RD&D manpower.

f. External Management Actions to Relieve Shortages

What recruiting or other policies need to be changed to respond to the conditions shown by the data? Sometimes both the existence and extent of forces affecting the employment situation and the measures used to counteract them are revealed in the statistical aggregates of the ad hoc actions taken by individual employers to meet the specific conditions they face. Where hiring is difficult, employers may resort to increased overtime that, when the situation is extensive, will show up as rises in the averages of paid overtime hours worked in individual industries published by BLS in their monthly series on Employment, Hours and Earnings (BLS 5). While these data apply to all workers, not just scientific, technical and professional workers, they are nevertheless useful as background indicators in the absence of data specifically identifying the precise occupational groups involved.

Some other responses by employers are not easily or ordinarily measured, but can be elicited by special surveys when the need for this information becomes important for policy decisions. Hugh Folk and his associates designed a survey to collect such information, and this experience could be used by DOE in special ad hoc surveys of employers in energy RD&D if at any time it appears that problems have arisen.*

Employer actions can involve reduction in hiring qualifications, redesign of jobs, subcontracting of work, cancelling of production or refusals to accept new work. In addition to establishing the nature of the employment situation, the information collected can also point to the prevailing remedies being used by employers to cope with the situation; sometimes these remedies also reflect employers' expectations that the problems are only short term. Where serious manpower shortage problems are suggested by other indicators, such special surveys may be worthwhile and gathering the information may become feasible if a vehicle such as the recommended Directory is established as a survey sample frame, or, alternatively, the Manpower Intelligence Network could be used to get information quickly.

*Folk, et al, op. cit., pp. 253 ff.

Sometimes, the data sources may reveal conditions not of shortage but of over-supply. Where the nature and dimensions of the situation can be determined by analysis of all of the relevant data, policy actions may be called for in areas of training support or in other areas where programs operate as inducements to enter or remain in the profession. Of course this would be a sensitive and complex subject involving study of a variety of factors and a consideration of long-term supply needs. Where indications of possible oversupply are allied to confirming data of overall economic slackness (in the data sources cited as providing a "background count" and in other relevant indicators), efforts to reduce the supply of specific STP might be ill-considered. Such efforts might be equally ill-considered if the evidence of oversupply was localized or connected with temporary program dislocations. In situations such as these, programs of mobility assistance could be considered, or holding pattern or talent stockpiling actions could be undertaken, including expansion of support programs. The subject is frequently controversial, and the potential actions are cited here not as recommendations, but as options that will inevitably be considered and will therefore require accurate and relevant data in the process of that consideration.

c. Equal Employment Opportunity

The present reporting system for ERDA laboratories and other GOCO establishments fortunately identifies the minority and female composition of employment and of employment actions -- although the occupational identification of these components is exceedingly broad. One approach to assessment of equal employment opportunity progress is to compare the composition of employment in the subject organization -- the laboratory or GOCO facility -- with that of similar or relevant employment in the community. The selection of the appropriate context is subject to a variety of criteria which have not been firmly established, but Census of Population data, after allowance for expected changes since the date of the Census, provide a variety of information by tract, locality and industry. In some cases, there are later data on employment in given localities or industries with information on minority and female composition by occupation. The data are admittedly sparse and often lack necessary detail, but use of a variety of indicators can identify apparent departures from fair employment policies. Where these are revealed, the next indicators to watch are those which reflect remedial (or aggravating) actions, namely those on hirings and promotions. The availability of expanded occupational detail in the internal reporting system of DOE and its contractors, recommended previously, would make the monitoring of employment practices a far more accurate operation.

B. ASSESSING THE MANPOWER OUTLOOK TO IDENTIFY PROSPECTIVE PROBLEMS

The question of the availability of qualified research personnel also becomes important in planning energy RD&D programs for several years ahead. This is especially true if major increases in program size are contemplated, but could also be true even without major program increases. Since the kinds of scientific and technical personnel required for research in the various energy technologies differ, a substantial shift in program emphasis, even without an increase in the total program size, would create different demands for manpower. Moreover, since other areas of employment compete with energy RD&D for some of the same kinds of specialists, a substantial change in any of these other areas might affect the availability of manpower for energy programs.

To assure the availability of "an adequate supply of manpower for the accomplishment of energy research and development programs" the DOE needs, therefore, first to estimate the future specialized manpower requirements of its own programs, those of other energy programs, and those of the competing areas of employment, and, second, to assess the future supply of trained personnel, which may be affected by the number of students now in the training pipelines, and such alternative sources for new workers as immigration and transfers from related occupations.

1. Estimating Requirements for Manpower

The primary concern of DOE must be its own requirements for specialized manpower for its energy RD&D programs (both internal and contractual). It is in a better position to make these estimates than anyone else because of its intimate knowledge of the field and of the changing content and direction of the research programs. DOE will also have considerable interest in estimating the manpower requirements for energy RD&D that are not generated by its own research programs but that arise out of research funded by other sources -- industry, state or local governments, or foundations.

Although the present report is confined to energy RD&D, DOE also has to be concerned with the non-research manpower needs of the energy-related industries (for construction, production, etc.) not only because of the breadth of DOE's responsibility for energy but also because non-research functions may compete for some of the same engineering, scientific and technician specialists and skilled craftsmen needed for energy RD&D.

Finally, the prospective needs of other industries and research programs for the same types of specialists have to be taken into account. With respect to these, DOE can count on information and estimates from other agencies concerned with assuring the availability of manpower for their missions, and of agencies generally concerned with manpower needs, such as the National Science Foundation and the Bureau of Labor Statistics.

a. DOE-Generated RD&D Manpower Requirements

The most dynamic force generating requirements for energy RD&D manpower is the DOE budget and resulting expenditures for research both in intramural laboratories and on contracts or grants. DOE therefore needs, as an essential part of its manpower information system, a method for estimating the manpower requirements for the various kinds of RD&D it supports. The most useful way of expressing these manpower requirements is in terms of the budget or reporting categories in which DOE's RD&D programs are organized, especially since these categories are capable of being divided into components related to the various energy sources and technologies. The critical need is for information on dollars of expenditure and manpower employed (and resulting cost-per-man ratios), classified by these categories.

Budgets, strictly speaking, are developed for the following fiscal year, and may be reduced (or sometimes increased) at various stages in the process -- in the Department, in the Office of the President, and in the Congress.

The firmest budget figures, therefore, are those farthest along in this process, and they provide guidance as to expenditures and manpower needs for shorter periods into the future. Nevertheless, an estimate of manpower requirements for the budget requested for the following year may be desired. For a somewhat longer-term outlook, the 5-year forward plans that have been made by Federal agencies would be the basic reference. These are usually expressed in terms of dollar expenditures. If DOE continues to develop long-term plans for energy RD&D as was done in 1976* these can be used as the basis for a projection of manpower requirements. Projections can also be generated independently from other data.

To translate expenditure programs expressed in dollars into manpower requires information on the numbers of various kinds of workers employed per dollar of expenditures. The reporting program on DOE intramural and contracted RD&D activity referred to in Chapter IV is designed to provide, for each type of RD&D by energy source or technology and by stage of progression (research, development, demonstration), a pattern of employment (by occupation) per dollar spent. These patterns will differ among projects -- even among projects classified as under the same energy technology. Moreover, the dollar/manpower ratios or the occupational mix may change over the next few years as the research programs move on to new stages.

The five-year Institutional Plans of the energy research centers and national laboratories (Pittsburgh, Bartlesville, Argonne, Brookhaven, Hanford, etc.), developed in 1977 for the first time, give some clues as to the expectations of research managers as to manpower requirements per dollar for each program, but few clues as to changes in occupational mix. The information provided is not consistent from plan to plan; all show projected RD&D operating and construction costs, by DOE budget or accounting classifications that are related to energy technologies, and the manpower requirements for each, projected to 1983 (in most instances). Only a few show the present occupational mix -- usually for the entire lab. Only one report comments on projected shifts in occupational mix:

*Energy Research and Development Administration, A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future, 1976. (ERDA 76-1). Washington, 1976.

No one is better able to make judgments as to future changes in dollar/manpower ratios or occupational mix than the project managers themselves, and it would be extremely helpful to the DOE's manpower analysis if such judgments were requested in the course of current and future 5-year institutional planning exercises.

For the RD&D work that DOE is having performed on contract, it should be possible to use the project proposals themselves as a source of information on the judgments of project managers on the occupational mix required and the likely manpower requirements of the project.

In using dollar figures for program projections over a period of several years, a question arises as to how to adjust for inflation -- specifically the general rise in salaries and other costs of RD&D programs, which has averaged 6 percent or more annually in recent years. If the dollar figures are considered firm, then allowance for inflation has to be made; if they are expressed in constant dollars, or if there is an assumption that the ultimate figures will be adjusted to reflect changing costs, then it is not necessary to adjust the manpower-per-dollar ratios derived from reported data. This point is mentioned only as a reminder that the issue has to be considered.

Manpower-per-dollar ratios are also affected by the state of the art itself, and the increasing availability of sophisticated and costly instrumentation and equipment for research.

The long-term energy RD&D plan of 1976 (ERDA 76-1, referred to above), or future plans of this type, represent a different kind of problem as far as development of manpower requirements projections is concerned. This plan was expressed, not in dollars but in terms of goals and rough timetables for each necessary step in development of each source of energy or energy technology. They could be translated into manpower terms either directly, by the program officials responsible for them, or after a dollar cost estimate has been made. If the dollar costs are based in part on a judgment as to the numbers of scientific and technical workers required to implement the plan's goals, then it were best to use the underlying manpower requirements projection rather than incur the danger of errors first in their translation into dollars and second in translating the dollars back into manpower -- possibly with different dollar-manpower ratios.

b. Requirements for Scientific and Technical Personnel Other Than Those Generated by DOE RD&D Programs

This category includes (a) manpower on energy RD&D not funded by DOE, (b) scientific and technical personnel in energy-related industries but not engaged in RD&D, and (c) all other scientific and technical personnel.

The DOE has an interest in current statistics on and future requirements for the first group -- how many are engaged in energy RD&D that is not funded by DOE and what will be the future manpower requirements for this work?

DOE also has considerable concern for the second group, not only because their work contributes to achievement of energy production goals, and in some cases is supported by DOE funds, but also because, being employed in energy-related industries, they are most readily available as a manpower resource for RD&D programs in the same companies.

DOE's interest in the third group is primarily as a component of the total supply of scientific and technical manpower, potentially available to meet the requirements of DOE as well as other demands.

An earlier section of this chapter discussed how an estimate of current employment on energy RD&D not funded by DOE might be made. Requirements for the future would depend on the financial resources available and on management judgments as to the pay-off of an investment in this type of research. There are data by which the resources available for R&D might be projected by each industry for future years, but little to go on, either in theory or in data, to project the management decisions as to the lines of research and development worth pursuing.

Resources available in each industry for R&D may be projected by using data on R&D expenditures per unit of sales in each industry sector and projections of industry sales volume. R&D expenditures per unit of sales for each industry are available for a series of past years from the NSF/Census Survey of Research and Development in Industry (NSF 4). The NSF has pioneered the careful analysis of these data and the trends they show covering the entire economy.* The trends in industry sales for the 10-year period up to 1985 were projected on the assumption that they would continue to increase at the same rate as in

*National Science Foundation, 1985 R&D Funding Projections. (NSF 76-314), Washington, 1976.

the recent past. Another approach to projecting industry sales, based on a more complex analysis of the market and technological factors affecting each industry within the context of the expected growth in GNP and national income, is illustrated by the Bureau of Labor Statistics' Economic Growth Studies.* From these, R&D expenditures can be estimated for future years and these can be translated into manpower by the ratios of scientific and technical manpower engaged in RD&D to expenditures.

How much of this would be in energy, is, however, more difficult to judge. As an oversimplified approach, one could take the percent of total R&D activity represented by energy R&D in each industry as of the most recent year and project this ratio for the future. Alternatively, one could assume that substantially all the R&D projected for the energy-producing, converting and distributing industries would be energy R&D. Neither of these methods of estimating takes into account the flexibility of research management in seeking new targets of opportunity opening up because of scientific break-throughs in one field or another, or market developments. In summary, projection of energy RD&D activity or manpower requirements (other than that programmed by DOE) can be done roughly, and with somewhat less reliability than the projection of total RD&D activity. DOE has a special interest in projecting this, because it is responsible for stimulating energy research.

Turning to the second group, scientific and technical personnel in energy-related industries but not engaged in RD&D, and the third group, scientific and technical personnel in all other industries, the recommended methods for making projections of requirements are identical, and have been used for a number of years by the Bureau of Labor Statistics (the Economic Growth Studies, referred to above, and their translation into occupational requirements in related publications**), the National Science Foundation (see above), the National Planning Association and other organizations.

*The most recent projections are summarized in articles in the Monthly Labor Review for March 1976 (pp. 3-21) and November 1976 (pp. 3-22). A critical review of earlier projections is published in the August 1976 issue (pp. 13-26).

**Department of Labor, Bureau of Labor Statistics, Occupational Projections and Training Data, Bulletin 1918, Washington, 1976.

Evaluations of these methods have found that they have produced estimates with a low degree of accuracy in earlier years, but have improved somewhat in more recent attempts as basic data and techniques have improved.* Recent research has added further to the technical and data resources.**

It is not recommended that DOE engage in the elaborate estimating process required, but rather should keep in touch with and review the work done by the BLS and NSF, discuss with them their plans for making projections, and assure that the plans meet the special needs of DOE. For example, the occupations projected should include all those of interest to DOE; the economic assumptions for the projections should include alternative energy development scenarios that are significant in DOE planning; and the future years for which projections are made should be the same as those needed by DOE in its own planning. The BLS and NSF should be persuaded to take DOE needs into account in making their projections. The projections so made need not distinguish between non-RD&D employment of scientific and skilled workers, employment in DOE-supported RD&D, and in self-financed RD&D. It would, however, provide a general background projection that would show the demands from other sectors of the economy for workers with the skills needed for energy RD&D.

The characteristics of this projection method will be summarized briefly here to show some of its features. The general approach is to estimate total manpower requirements in the target year in each sector by estimating the production or activity required to meet the expected market demand, and then, from information on the occupational composition of that sector estimate the requirements for each occupation. Market demand for the output of each sector is estimated from the demand for final products generated by the total income of the major purchasers: consumers, government and capital investment of business.

*National Science Foundation, Proceedings of the Seminar on Scientific and Technical Manpower Projections, April 16-18, 1974. Washington, 1976.

**Hugh Folk, et al, Scientific and Technical Personnel in Energy-Related Activities: Current Situation and Future Requirements. Center for Advanced Computation, University of Illinois, Champaign-Urbana, Ill. July 1, 1977.

A potential gross national product is projected on the basis of labor force growth and projected changes in output per worker hour and average annual hours. This GNP is divided among consumers, government and investors by application of an economic model. The patterns of purchases by each of the three major elements are used to estimate how they will divide their expenditures among final products or services. The production of raw materials, components or services by all supplying industries that is needed to generate these final products or services is then estimated by applying input/output tables for the United States economy, which show how much each sector buys from and sells to every other sector. What results is an estimate of the production load in every sector of the economy in the target year.

The employment required in each industry to produce this amount is then estimated by projecting output per worker hour and average annual hours per worker. The occupational composition of each industry is used to calculate the requirements by occupation, and the totals for each occupation are aggregated across industries.

Most of the ratios used are not the present or most recent ratios, but rather ratios projected for the target year; this includes output per worker hour, hours, occupational composition, interindustry input/output coefficients, and purchasing patterns of consumers, government and investors.

Estimates for some economic sectors are exogenous to this system; for example, employment of school and university faculty is estimated on the basis of projected enrollments which are made from projections of the population of school age and trends in school enrollment.

The disaggregated treatment of the economy in this system makes it possible to introduce special assumptions, estimates or scenarios of interest to DOE, to test the effect of various policy alternatives on the various elements estimated, including production and employment by sector, employment by occupation, national income, capital investment, etc.

This method gives estimates of total employment by occupation in each industry or sector of the economy. If DOE has made separate projections of employment on DOE contracts in some sectors, these are not additive, since the base year occupational employment data used in the projection system may contain some workers employed on DOE contracts, and they would be treated as part of the manpower in the industry, related to projected production levels. It is essential to identify separately the DOE-supported employment on energy RD&D in the base year so that it can be subtracted from the industry's total employment before computation of the non-DOE-generated RD&D employment associated with projected production levels. The amount of energy RD&D employment not supported by DOE is related to the levels of the industry's sales, and so should be a component of the total scientific and technical employment projected. If a separate estimate of this RD&D employment is made, it should not be added to the employment requirements estimated by the economic demand approach since it is already comprised in the latter. The integration of R&D projections with general economic projections is a goal that requires careful consideration and cooperation among the agencies involved.

There are serious methodological problems associated with these projections, requiring additional research. One is the projection of occupational composition of industries, especially with respect to scientific and technical personnel, whose relationship to the production process is not as close as that of various production workers. Some of these issues are discussed by Folk and his associates.* For example, how similar is the occupational composition of the various plants in an industry, and what factors affect the differences -- are they effects of scale, or technological differences, or does management have considerable flexibility in utilization of different proportions of the various occupations in response to market factors (salary levels or availability of the different occupations)? The answers to these questions affect the projections that will be made. Because of their relevance to DOE concerns, the DOE should encourage or support research on these issues.

*Folk, et al., op. cit., pp. 151-160.

2. Projecting Supply of Manpower

The approach and emphasis in measuring and projecting supply differs from those used for manpower requirements. The above discussion of methods for projecting manpower requirements began with energy RD&D personnel working on DOE-supported projects, and then moved on to personnel employed on energy RD&D with funds from other sources, and, further, to all other persons in the same occupations who are employed in other work - either in non-research work within energy-related industries or in other industries. In considering the supply of these workers, however, all members of these occupations in the United States will be considered together.

It is necessary to recognize that the supply, so conceived, is not homogeneous. There are differences among members of any occupation or scientific specialty with respect to their ability to engage in various kinds of RD&D in the very broad and diversified field of energy. An electrical engineer whose experience is in the construction and design of telephone communications facilities, or even one engaged in research on photovoltaic electricity generation, may not easily adapt to work on the design of Tokamak fusion reactors. While members of these occupations are not fully interchangeable, it is reasonable to assume that with sufficient opportunities for special training and experience there is considerable flexibility within each professional field, so that all members of these occupations may be considered potential participants in one phase or another of energy RD&D. At any rate, their qualifications are in general more relevant than those of workers not in these occupations.

In estimating the prospective supply, we must start with the present supply, deduct prospective losses and add prospective increments.

a. Present Supply or Labor Force

Data on the numbers and characteristics of the present supply may be developed as was described at the beginning of this chapter in discussing present employment. In addition, present supply includes those now in the labor force but unemployed. In the occupations involved in energy RD&D, the unemployment rate is typically very low, as it is among professional and technical workers generally. The numbers and characteristics of unemployed members of these occupations can be obtained from the National Sample Survey of Scientific and Technical Personnel (NSF 15) and the sample surveys of the NAS/NRC doctorate file (NRC 2). In general, supply and requirements estimates are so approximate that the additional precision achieved by adding the 1 to 3 percent who are unemployed is not always worth the effort.

The significant characteristics for analysis of labor supply are age and sex (essential in estimating losses from death and retirement), educational attainment (level and field or fields of education -- which are not always fully described by field of degree, since many scientists with degrees in one field have had substantial training in others), and fields of work experience (industries in which employed, areas of research in which work was conducted). Data are not readily available on all these subjects in the general statistical sources.

b. Prospective Losses

The principal kinds of losses to the supply of workers in an occupation are deaths, retirements (or temporary withdrawals from the labor force, which have been particularly significant in the case of women), transfers to other occupations, and emigration. To estimate the future supply available to meet projected requirements, these must be separately estimated for the period from the base year to the target year.

i. Deaths: The most recent Life Tables for the United States published by the National Center for Health Statistics, Public Health Service, Department of HEW should be used, together with the most recent available data on the composition of each occupation, by age and sex.

The most recent Life Tables as of this date are for 1975, and will shortly be published in Vital Statistics of the United States, 1975, Vol. II, Mortality, Part A.

The age and sex composition of members of each occupation are available in the sources used to get information on the present labor force -- the Census of Population, the National Sample surveys of scientific and technical personnel (NSF 15), and the sample survey of Ph.D.'s by NAS/NRC (NRC 2).

The fact that the National Sample surveys do not include graduates since the census was taken do not invalidate their use to estimate deaths, since the number of persons dying within ten years after graduation is negligible. However, there may be a significant number of deaths among persons who had entered the occupation from other occupations since the last population census, or from among immigrants who entered the occupation. Therefore, to the deaths estimated for the occupation at ages should be added an allowance for deaths among these entrants. This will be discussed below under occupational transfers.

The computation of deaths in an occupation, over a period of years in the future should not be made from one-year death rates for an age group. Since death rates rise by age, the death rate for a population cohort will be higher at the end of, say, a 10-year projection period than in the first year. The death rates taken from the Life Table should be rates for the entire period of the projection. These can be calculated for each age group by subtracting from the number of persons in that age group in the L_x column of the life table the number of persons in age groups Y years older (Y being the number of years from the base year of the projection to the target year), and dividing the remainder by the number in the L_x column for the age group in the base year; this gives death rates for the age group in a period of Y years.

ii. Retirements: Data from the 1970 census tabulations of 1965-1970 changes in status (BLS-4) are the best information on differential occupational retirement patterns currently available. Since the retrospective data for 1965 status was found to be subject to error especially for persons with a weak attachment to the labor force, such as youths, women and older persons, they were adjusted to make the age and sex composition in each occupation for 1965 follow the pattern in 1970. This is a reasonable adjustment for all occupations except those fast-growing occupations with many young entrants, or slow-growing occupations with few new entrants, or occupations in which women have gained a significant proportion of jobs in the 5-year period.

The 5-year separation rates for men in the scientific and technical fields range from about 4 to about 6 percent, and for women from about 20 to about 25 percent.*

For the scientific and technical occupations not shown in the tabulations, either because they were not separately identified in the census or because the sample was too small to yield estimates with a sampling error of less than 10 percent, it is recommended that the separation rates for the most similar occupations that are shown in the tables should be used: for engineers of various categories, the rates for all engineers; for women scientists the rates for all women professional, technical and kindred workers; etc.

iii. Transfers to other occupations: As noted in chapter IV, data on inter-occupation mobility show that the such changes are extensive and therefore should be taken into account in assessing the prospective supply of workers in any occupation; but it was also noted that there were significant reporting errors in the principal source of general information on inter-occupational shifts. It will be a long time before recommendations made in Chapter IV for improvement in the data can be effectuated.

In making projections of supply, therefore, it is recommended that the net of transfers in and transfers out of each occupation, as shown in the 1965-1970 change tabulations from the 1970 Census (BLS 4) be used, with caution.

iv. Emigration: There are few data on this subject (pending achievement of the program recommended in Chapter IV), and therefore almost no quantitative account can now be taken of this component in labor supply changes. A certain number of immigrants leave after working in these occupations for a period of years, some to return to their home countries, others to go to third countries. INS data collected up to 1957, and limited studies made since, confirm this. In addition, some native-born scientists and engineers have emigrated. Perhaps failure to take account of emigration

*Dixie Sommers and Alan Eck, "Occupational Mobility in the American Labor Force," Monthly Labor Review, January 1977, p. 9.

in these occupations offsets errors in underestimating immigration, though the latter is less likely in scientific and technical occupations.

c. Prospective Increments

The principal sources of prospective increments to the supply in an occupation are entrants completing their training in schools, colleges, apprenticeship programs, etc., transfers from other occupations, immigration, and the return to active work in the occupation of experienced workers who had withdrawn temporarily, principally women who had dropped out for family reasons.

i. Entrants from educational or training programs: The statistics on the numbers completing training -- earned degrees granted by institutions of higher education (NCES 1), associate degrees and other formal awards below the baccalaureate (mainly, in community college and technical institute 2-year programs) (NCES 3), completions of apprenticeships in registered programs (ETA 4) and others -- give the information on the number of persons who have already completed various courses of training. If the base year for projections is several years ago, these statistics help to fill in the picture of the supply of newly-trained persons for part of the period between the base year and the target year.

The number of trainees already in the pipelines determine the output of these programs several years ahead. Information on the numbers of undergraduate students in their junior and senior years (NCES 4), of graduate students, by major field of study (NCES 2) and on apprenticeship enrollments (ETA 4) can be used, together with data on the ratios of enrollments to degrees granted in subsequent years (or of registered apprentices to completions) that may be developed by examination of past relationships in the statistics, to estimate the number of completions or degrees that will be granted in the next few years.

Beyond those few years, the projection of the number who will complete training is more problematical, for it is dependent in part on the choices made by students -- first, whether to enroll in apprenticeship, in community college programs, in 4-year colleges, in professional schools (engineering, law, medicine, etc.) or in graduate studies, and, second, as to what specialties they will select. These decisions are affected by many factors including the values and life-styles students aspire to, and also their information as to employment and earnings opportunities in the various occupations.

At times, when jobs are hard to get, an increased number of doctoral graduates accept postdoctoral research grants in universities, partly for further training or research opportunity, but also partly as a holding pattern until they can land in a job. This has to be taken into account in appraising the supply.

As noted above, Chapter IV, the NCES makes projections of college degrees by field on the basis of expected change in population of college age and of recent trends in enrollment in the various courses of study. It is recommended that if these are used by DOE, they should be considered, not as actual predictions of what will really happen, but as first approximations -- illustrating the balance of supply and requirements that would occur if students had no information that might lead them to change fields of study from their recent patterns of selection; DOE will want to assume that information will be made available to students and that changes in these patterns of choice of field may result.

The National Science Foundation has developed methods of projecting the numbers of college entrants, baccalaureate degrees, enrollments for advanced degrees in science and engineering, and doctorates in these fields on the basis of not only the past trends, but also with an adjustment to give more weight to recent trends that reflect market and life-style factors. It is suggested by NSF that the two separate estimates present a range within which the actual figures may eventually fall.*

For apprenticeships and community college or technical institute 2-year programs it is recommended that no attempt be made to make projections, in view of the limited basis for analysis of trends in these types of training, but that the recent data on completions be used as a first approximation of prospective completions -- i.e., making the initial assumption that present training patterns will continue.

*National Science Foundation, Projections of Degrees and Enrollment in Science and Engineering Fields to 1985. (NSF 76-301), Washington, 1976.

ii. Transfers from other occupations: The recommendation under the discussion of losses as a result of transfers to other occupations was that net transfers shown by the 1965-1970 change tabulations of the 1970 census (BLS 4) be used as a basis for that estimate. This therefore covers the transfers into the occupation as well.

iii. Immigration: The weaknesses of data on immigration by occupation were noted in Chapter IV. All that can be recommended at this point is that in making projections allowance be made for immigration using the most recent data from the Immigration and Naturalization Service, with suitable caution.

iv. Return to the labor force of experienced workers: The bulk of those who withdraw from and subsequently return to the work force are women who drop out for family reasons. While in general there have been relatively few women in the scientific and technical and craft occupations involved in energy RD&D, there are substantial numbers in a few of the occupations, and generalized efforts to increase their numbers in all of them. In the absence of better data, the net transfers between employment in each occupation and non-labor force status, as shown by the 1965-1970 status tabulations from the 1970 census (BLS 4) may be used, with caution. In most cases the data for women had sampling errors so large that they were not published by BLS; in such cases the general net change rates for the scientific and technical occupations should be used, applied to the women in the specific occupation.

3. Assessment of the Requirements/Supply Balance and Its Implications

The methods for projection of requirements and supply outlined above have treated them independently of each other, without allowance for the interaction that in reality occurs between demand and supply. The requirements and supply projected have been predicated on the continuation of recent past patterns or trends in patterns of economic and technological relationships, with price, wage and market factors held constant or changing as in the recent past. Both requirements and supply will, in fact, be affected by each other.

The principal element of requirements that is responsive to supply and market consideration is the way in which employers utilize members of the various occupations to get their work done. If supply is short and wages in a particular occupation increase more than in others, or qualified workers become hard to hire, employers will seek to substitute less-qualified workers, or workers from other occupations, or will seek to change the production process to utilize fewer of the scarce or expensive workers. These adjustments are, however, difficult to make, especially in research and development programs, which typically require specialists of the highest abilities, with limited possibility of substituting other workers. Moreover, in the case of research subsidized by government contract, moderate increases in salaries for some scientific and technical workers are not usually a barrier to continued pursuit of the project. A relative shortage of supply is therefore likely to have a minimum impact on demand unless the shortage is extreme.

In an oversupply situation, employers tend to raise hiring standards, or to employ highly qualified workers for less demanding jobs, and entrance salary levels tend to fall, or, in an inflationary period, to remain stable while all other salaries are rising.

Adjustments are much more feasible in the supply than in requirements. In the short run, employers can sometimes find qualified workers who are employed in non-research work, or who are working in other occupations but have had some training that at least partially qualifies them for the job at hand. Short-term training or special courses help to qualify partially qualified workers. In the longer run, students respond to signals from the labor market by switching courses, entering graduate study in fields with good employment opportunities, etc. Educational institutions are sometimes responsive -- offering special courses in shortage fields or expanding enrollments or facilities. For these reasons the projection of enrollments and completions of training programs, made provisionally on the basis of past patterns of student choice, are subject to revision as information on employment opportunities becomes known.

DOE, after assessing the prospective requirements and supply of skilled workers for its energy RD&D programs, should therefore take pains to inform students and educational institutions of its findings, through channels available to it, including direct contacts with institutions, government agencies providing information on employment opportunities to students and schools, (such as the Bureau of Labor Statistics, National Science Foundation, Office of Education, and State employment security agencies affiliated with the Employment and Training Administration of the Labor Department), and private agencies such as the Scientific Manpower Commission and the Engineering Manpower Commission.

The DOE may find implications for its own policies in the prospective supply/demand situation. Programs to encourage students to enter fields of special concern to DOE through student aid may be enhanced or reduced on the basis of such information, or support of graduate students through research grants could be affected. Similarly, efforts to strengthen certain university departments through research grants might be affected by judgments as to the adequacy of the present rate of output of graduates as well as the quality of the education given. Contract award policies may need to anticipate changes in salary levels for scientific and technical personnel in response to prospective changes in the supply/demand situation.

CHAPTER VI

THE CURRENT MANPOWER SITUATION

A. INTRODUCTION

On the basis of information now available from the principal sources described above, a preliminary assessment of the balance of supply and demand for energy-related manpower is attempted in this chapter. Obviously, this assessment cannot be as definitive as one using the manpower information system recommended elsewhere in this report. It will however, illustrate concretely the potential uses to be made of the data and some of the problems in their interpretation, and may be helpful to the Department of Energy.

The general economic background will first be discussed, and then the labor market situation for scientific and technical personnel and the energy industries, as they may impinge on manpower for energy RD&D programs. A final section will discuss future requirements for scientists and engineers in energy R&D.

B. ECONOMIC BACKGROUND

1. The Overall Economy

After a rapid upturn from the 1975 recession, economic growth has slowed in 1977, and no acceleration is anticipated for the coming year.

The Gross National Product, which had risen in real terms at a 4.6 percent rate from the third quarter of 1976 to the third quarter of 1977, was growing more slowly at the end of this period.* A slower rate of growth than that of this year is generally anticipated for 1978. Total employment rose by 4 million (4.4 percent) in the year ending November 1977, more than double the annual rate of the past decade. Unemployment, which fell from 7.6 percent in October 1976 to 7 percent in April 1977, remained at about that level for the following seven months, despite a growth of 2.2 million in employment as more people

*U.S. Congress, Joint Economic Committee, Economic Indicators, Washington, October 1977.

entered the labor force*; efforts to alleviate unemployment made no dent in the total.

2. Employment and Unemployment of Highly Trained Manpower

Unemployment of professional and technical workers has remained at about 3 percent since April, typically lower than for all workers, after declining from 3.3 percent in the fourth quarter of 1976. Unemployment for these workers is nevertheless significantly higher than during the post-World War II period as a whole.

Employment of engineers increased in 1977, but there was no significant change in employment of scientists or of engineering and science technicians.**

Unemployment of engineers in 1977, averaging under 1-1/2 percent through the third quarter, has been about one-half, or less, that of professional workers among whom engineers are included. The decline in engineering unemployment from the recessionary high levels of 1975 and 1976 has been considerably greater than that of the overall professional group, a large proportion of which is teachers who have experienced serious employment problems recently. Even as low as unemployment among engineers has been this year, however, their rates are still above those during the second half of the 1960's, which were typically below one percent.

Information from a separate source tends to confirm the reduction in unemployment for scientific and technical personnel: chemists' and chemical engineers' unemployment declined from 1.9 percent in March 1976 to 1.5 percent in March 1977.***

Recent improvement in unemployment among craftsmen has also been greater than among professional workers as a whole. Unemployment of craftsmen fell from 7 percent in the fourth quarter of 1976 to about 5 percent in the most recent six months, but this is also higher than the postwar average.

*Employment and Earnings, November 1977, supplemented by data for November issued on December 2.

**Bureau of Labor Statistics, unpublished data.

***American Chemical Society, Report on Chemists' Salaries and Employment Status, 1977, Washington, 1977.

In sum, even with substantial reductions in the unemployment of professionals as a whole (and even greater improvement among engineers and craftsmen), and with large employment increases among all of these groups this year, the unemployment rates for these groups do not suggest the tight labor market conditions of several prior years.

3. Energy Industry Employment

Total employment in the energy industries has grown faster than all non-agricultural payroll employment in the year ending in September 1977. The energy sector's workers increased by 5.2 percent as compared to 4.3 percent for all workers on nonfarm payrolls. The greatest increase was in oil and gas extraction (13.2 percent), but coal mining employment also rose faster than the total (5.9 percent). Petroleum refining and electric and gas utilities grew less than the total.

4. Federal Expenditures on Energy RD&D

Federal energy RD&D expenditures, a major generator of energy RD&D employment, will be going up more slowly in the 1978 fiscal year than in fiscal 1977. An increase of 15 percent is anticipated for the present year, compared to the 66 percent increase in the past year.* Among the fastest-growing programs this year are those on end-use conservation and technologies to improve efficiency, fuel cycle R&D, geothermal energy development, petroleum and natural gas, and electric energy systems and energy storage. (These categories are from the NSF report.)

Energy R&D expenditures are rising twice as rapidly as the total Federal R&D budget, which is going up by 7.5 percent this year. (Only the relatively small item of "international cooperation and development" is increasing more rapidly than energy R&D.) All major programs in the natural sciences are expanding in terms of dollars this year, but since R&D costs (including salaries of scientific and technical personnel) are rising, the actual increase in employment will be smaller. The 15 percent increase in energy R&D will result in an employment increase for these programs of perhaps half that amount.

*National Science Foundation, Defense and Energy Spur Federal R&D Growth from FY 1974-FY 1978, Science Resources Studies Highlights, (NSF 77-320), September 30, 1977. (The figures above differ slightly from those shown in the NSF report, the main difference being the inclusion of energy-related environmental research included by NSF under "environment.")

In recent years work in energy and fuel has attracted a greater share of the engineers and scientists. This can be seen in the 1974 and 1976 employment of those identified in the 1970 Census of Population as members of these professions (NSF 15). The share of all scientists and engineers in energy and fuel increased from 10.4 percent in 1974 to 11.8 percent in 1976, and an increase occurred in each individual field. (Since these data do not include the new graduates and other entrants since 1970 they are likely to understate the proportions flocking to expanding fields of work.) About half the earth scientists, but only about one in seven of the engineers and physicists and one in twelve of the chemists were in energy and fuel work.

C. THE CURRENT LABOR MARKET SITUATION FOR SCIENTIFIC AND TECHNICAL PERSONNEL

The increased hiring activity associated with rising employment of engineers has been reflected in an increase in the Deutsch, Shea and Evans Engineering and Science Demand Index (DES 1), which was sharply up in the first eight months of 1977 -- higher than any year since 1966.

The demand for scientific and technical personnel, as reflected in relative salary rates, has been generally similar to that for other professional, administrative and technical workers surveyed by BLS in the PATC survey in the last few years. Earnings of engineering technicians and chemists have increased slightly more than those for all workers in the group; while those of engineers have risen slightly less (BLS 1). Among these occupations only the earnings of engineering technicians have kept pace with the average wage rates for all production and non-supervisory workers on nonfarm payrolls (as shown by an index that eliminates the effects of shifting employment weights among industries and the effects of overtime premium pay in manufacturing) (BLS 5). All of these increases have barely kept ahead of the Consumers' Price Index.

Current indicators of the supply/demand situation for scientific and technical occupations show that the active recruitment that took place with the 1977 graduates is expected to continue with respect to the Class of 1978. The College Placement Council's survey of employers' hiring plans (CPC 2), released December 12, 1977, showed an increase in hires. Reports from other agencies following the recruitment scene (as summarized in Scientific Engineering Technical Manpower Comments, November 1977) agree that the labor market is particularly active for the technically trained, especially engineers, scientists, and computer personnel. This active market follows a period of relative quiet in the early 1970's.

On the other hand, R&D, on which approximately a third of the scientists and engineers are employed, is expected to show only token real growth insofar as Federal Government funding is concerned for 1978, according to NSF (as noted above). There will be, of course, program adjustments with energy R&D showing some increase. For most technical fields, the universities will be graduating about as many new degree holders as in the recent past.

There do not appear to be many serious shortages in the supply of STP for energy RD&D at this time. A review of the available indicators, supplemented by interviews with R&D program managers, shows only a few occupations for which this generalization appears less true. Parenthetically, the supply of STP for energy RD&D is in general the same supply as for all R&D, or for all activities in the given occupations.

Coal mining engineers. A recent ERDA report, Manpower for Coal Mining,* points out the current short supply of coal-mining and coal-preparation engineers at both the bachelor and graduate degree levels. These findings appear to be confirmed by interviews with fossil fuel officials and representatives of major energy production industries in a survey made by NSF in March 1977.** The current shortage is likely to be temporary, however, since undergraduate enrollments in mining engineering are sharply increasing and in-house retraining of available engineers trained as civil, chemical, electrical and other serves to alleviate the shortage.

Petroleum engineers. The NSF survey of March 1977 found this occupation in tight supply at all degree levels. The Engineering Manpower Commission reports median salaries to be the highest for any engineering field at $25,250 per annum in 1976. New bachelor level graduates averaged $18,000 in 1977, the highest among all engineers, and 8 percent more than in 1976 according to the College Placement Council, which seems to confirm a tight supply situation.

*TID-27669, September 1977.

**National Science Foundation, Current and Future Utilization of Scientific and Technical Personnel in Energy-Related Activities. NSF 77-315, Washington, June 1977.

Chemical engineers. This occupation was also found in tight supply in the NSF survey. Confirming evidence as to shortage was reported by the College Placement Council for 1977 recruitment, and the American Chemical Society found average starting salaries for inexperienced bachelor degree holders up 9 percent in 1977. Chemical and Engineering News reported employment increasing over 1976 with a further increase forecast by chemical employers of 3 percent by mid 1978. ACS members (including chemists as well as chemical engineers) reported an unemployment rate of only 1.5 percent in March 1977, down from 1.9 percent a year earlier. An independent study* of chemical engineers anticipates an increasing demand for chemical engineers with emphasis shifting from the petroleum-related to other industrial sectors. Average net additional requirements of 2,000 per year over the next 10 years, a substantially higher rate than projected by BLS, compares with current bachelor graduating classes of about 3,000. When allowance is made for deaths and retirements, the number of graduates at this level implies a continuing tight supply. However, the American Institute of Chemical Engineers reports first year enrollments for 1976 up 16 percent (see Chemical Engineering Progress for March 1977). Employment of new graduates is expected to continue rising into 1978. (C&EN survey of chemical employers).

Chemists. Principal energy RD&D requirements in this occupation are reported in organic, physical, and analytical chemistry. The ACS reports marked improvement in demand for chemists over the past year. (Chemical and Engineering News for October 24, 1977.) The unemployment rate for ACS members (including chemical engineers) was reported to be lower in the Spring of 1977 than a year earlier, as noted above. Chemical industry employers are increasing their employment of chemists with further increases expected in 1978. Industry R&D employment is up and expenditures are expected to increase by a further 9 percent in 1978. Median annual starting salary rates for inexperienced chemists confirm an active demand, increasing 11 percent in 1977 over 1976. Starting salaries for doctoral degree holders (up 7 percent) reflect a weaker market, probably influenced by the large number of chemists engaged in post doctoral programs, although fewer new doctorates reported such positions in 1977.

*James Cummings-Saxton: "Market Demands and Educational Supply of Chemical Engineers, 1976-2000", reported in Manpower Comments, November, 1977, p.3.

Environmental scientists. The multi-disciplinary field of environmental research and study shows promise of developing into a category of science and technology likely to face an active labor market over the near term future. The energy program emphasis on development of fossil and nuclear fuel sources will require professionals with training in atmospheric, terrestrial, hydrological and biological fields for appraisal of effect and prevention of adverse impact upon the ecology. Specialties such as atmospheric chemistry and physics, soil and agricultural chemistry, hydrology, ecology and others are included in the active demand for environmentalists. This field will become more active as research emphasis shifts to development and demonstration. Doctorate production in ecology shows promise at least of sharp expansion for the biological side, with the American Council on Education reporting an approximate doubling of such degrees expected between 1976 and 1980. The physical science and engineering areas and the bachelor level may not expand as flexibly.

Other scientific and technical occupations. Numerous other occupational specialties have come to our attention and have been reviewed, insofar as available information permitted, from the standpoint of possible limiting effect upon energy RD&D. These include some small numbers of highly specialized skills such as electro-chemistry and plasma physics which may present problems on specific programs. Other occupations considered were not believed to present serious problems at this time, including such engineering fields as civil, electrical, mechanical, industrial, systems, materials, and nuclear, and science fields of metallurgy, physics, geology, mathematics, and economics.

D. FUTURE REQUIREMENTS FOR SCIENTISTS AND ENGINEERS IN ENERGY RD&D ACTIVITIES

It is estimated that as of 1975, about 15 percent of the scientists and engineers employed by private industrial concerns were engaged in energy-related activities. About one-fifth of this group -- or about 3 percent of all industrial scientists and engineers -- were involved in energy RD&D. Energy RD&D scientists and engineers were about 7 percent of all of those in research and development work.*

* National Science Foundation, op cit.

Few analysts have attempted to project future requirements for personnel in energy RD&D activities. Not only is it difficult to project total requirements for energy scientists and engineers, because of the lack of a clear-cut plan for energy development, conversion, and conservation, but the needs for energy research, development and demonstration are even more uncertain at this time. This should not be surprising since R&D activities in general are by their very nature difficult to predict. Furthermore, specific plans for the level and type of energy RD&D programs for some future time (e.g., 1985) await scientific and technical progress to that point, based on economic and political decisions made in the next few years.

The most recent and comprehensive attempt to project scientific and engineering employment in energy-related activities was undertaken by the Center for Advanced Computation (CAC), under contract to the National Science Foundation.* This effort was based on earlier work done on manpower and energy models by the Center. Selected results of the Center's study and a 1975 survey of employment of scientific and technical personnel in industry were released by NSF.** Analysts at the Center incorporated the latest available energy scenarios available from ERDA, which were included in the 1975 National Plan for Energy Research, Development, and Demonstration (developed prior to the establishment of the DOE).

The three energy scenarios examined are called Free Imports, Limited Imports, and Limited Imports Synthetics which imply different final demand, prices, and technology patterns. The scenarios were analyzed against a backdrop of information on overall national patterns of goods and services production and employment prepared by the Bureau of Labor Statistics. The input-output matrix used consists of non-energy coefficients projected by BLS and energy industry coefficients developed by CAC.

The findings of the CAC study show that the range of requirements for all scientists and engineers and those in energy activities under the three scenarios is very small. Using a base of 1,200,000 scientists and engineers employed by industry in 1974, the projected requirements for this sector for the Free Imports

*Hugh Folk, et al, op. cit.

**NSF, op. cit.

and Limited Imports scenarios were estimated at 1,650,000 -- a growth of 37.5 percent, or an average of 3 percent annually. Furthermore, it was estimated that about the same proportion of all scientists and engineers would be involved in energy programs under the three scenarios -- 13 percent. No separate estimates of manpower engaged in research and development were made.

There are several reasons why these decidedly different scenarios produced essentially the same overall results. Scenarios based on development of new domestic capabilities also assume a reduction in imports, resulting in a lower use of energy. This lower level reduces not only the total demand for industrial scientists and engineers, but also those in energy. Additional manpower requirements for the construction and operation of nuclear power plants to expand coal and synthetics use and to do research on new technologies essentially offset reductions from declines in non-nuclear electric power production, in petroleum extraction and refining, and natural gas production, and other decreases resulting from reduced energy use.

Thus, under any of the three scenarios, these projections indicate a likelihood of an annual three-percent growth rate in employment of scientists and engineers for all needs in the economy; and the proportion of these personnel involved in energy production does not change significantly. Behind this overall growth rate are widely varying rates for individual occupations, energy activities and industries. Substantially faster growth than the average will occur in some fields, possibly presenting serious manpower problems. For example, requirements for civil and petroleum engineers, mathematicians, computer specialists and draftsmen are estimated to rise up to 50 percent faster than the average. While these analyses do not take into account the future supply of personnel to meet requirements in energy and the total economy, the rapid growth in requirements in some specialized fields may present the nation with serious shortages unless steps are taken to anticipate and deal with them.

APPENDICES

APPENDIX A

TAXONOMIES FOR THE CLASSIFICATION OF DATA RELEVANT TO ENERGY RD&D MANPOWER

Table of Contents

APPENDIX A

TAXONOMIES FOR THE CLASSIFICATION OF DATA RELEVANT TO ENERGY RD&D MANPOWER

In Chapter II and in other places in the text, references are made to various taxonomies relevant to the classification of energy, energy RD&D, manpower, and other measures of activity. In some cases, where the listing is relatively short or simple, the complete taxonomy is given, as in the case of the details of character of the work included under RD&D (Section B in Chapter II). In others, an abbreviated listing of the categories is presented in the text. Finally, references are made to taxonomies not shown in the text.

The following then are a series of taxonomies showing either greater detail than given in the text or being displayed only for informational purposes to illustrate the scope and boundaries of energy activities. The separate taxonomies in some cases have established numbering systems, e.g., B3 below.

A. RESEARCH, DEVELOPMENT, AND DEMONSTRATION:

(Character of Work, Sectors of the Economy, and Fields of Science) Shown in Chapter II, Section B

B. ENERGY ACTIVITIES:

1. <u>Energy Sources</u>

   a. Fossil

      i. Coal
      ii. Natural gas
      iii. Petroleum
      iv. Oil shale
      v. Tar sands

   b. Solar

      i. Thermal
      ii. Electric

   c. Wind

   d. Ocean

      i. Thermal
      ii. Motive

   e. Geothermal

   f. Photosynthesis, bioconversion

   g. Hydroelectric

   h. Synthetic fuels (hydrogen, methane)

i. Other

   i. Plant and animal by-products
   ii. Urban and industrial waste
   iii. Water resources

j. General and multi-source

2. Energy Stages

   a. Exploration - search for or disclosure of raw primary sources of energy.
   b. Extraction or recovery - removal of primary source from original location.
   c. Refining - benefication, upgrading, purification, reprocessing, or other treating of primary sources.
   d. Fuel conversion - coal gasification, uranium and thorium conversion, biomass to fuel, etc.
   e. Energy conversion - fossil-fueled power plant, fission and fusion (LWBR, HTGR, LMFBR), hydroelectric, ocean thermal, photovoltaic, solar heating and cooling, wind generation of electricity, etc.
   f. Transportation and transmission - trucking, shipping, railing, and piping of raw or refined sources.
   g. Distribution - processes of energy reaching final consumer (electric lines, wholesale and retail gasoline sales, etc.)
   h. Storage - accumulation of raw, refined, or converted sources, including electric (compressed air, batteries, salt mines, etc.)
   i. Utilization - improved conservation or efficiency of energy and use--in industrial, commercial, transportation or residential uses. This area includes conservation of basic sources for non-energy uses.
   j. Waste disposal, removal or treatment - by products or end products of original sources of harmful or no potential use.

As indicated previously, there can be conservation; research, development, and demonstration; environmental concerns, and basic science support applicable to any of these stages.

3. Energy Budget and Reporting Classifications*

(Follows on next page)

* In most categories, operating and capital and equipment costs are available as separate items.

Mission Resource	Activity	Subactivity	Task	
A				ENERGY SUPPLY - RESEARCH AND TECHNOLOGY DEVELOPMENT
AA				Coal
	01			Mines Research and Development
	02			Liquefaction
		01		Direct Hydrogenation
		02		Solvent Extraction
		03		Pyrolysis
		04		Indirect Liquefaction
		05		Support Studies and Engineering
		06		Liquefaction Demonstration Plants
		07		Special Foreign Currency - Liquefaction Projects
	03			Gasification
		01		High-BTU Gasification
		02		Low-BTU Gasification
		03		In Situ Coal Gasification
		04		Gasification Demonstration Plants
	04			Advanced Power Systems
	05			Direct Combustion
		01		Fluidized-Bed Boiler - Atmospheric
		02		Pressurized Systems
		03		Coal-Oil Slurries
		04		Support Studies and Engineering Evaluations
		05		Direct Combustion Demonstration
	06			Advanced Research and Supporting Technology
	07			Magnetohydrodynamics
		01		Open Cycle Plasma Systems
		02		Applied Research
		03		Special Foreign Currency - MHD
AB				Petroleum
	01			Enhanced Oil Recovery
	02			Oil from Oil Shale
	03			Drilling, Exploration and Offshore Technology
	04			Product Characterization and Utilization
AC				Gas
	01			Enhanced Gas Recovery
	02			Gas from Oil Shale
AD				Solar
	01			Thermal Applications
	02			Technology Support and Utilization
	03			Solar Electric Applications

AD Solar (continued)

01 Solar Thermal Power
02 Photovoltaic Energy Conversion
03 Wind Energy Conversion Systems
04 Ocean Thermal Energy Conversion
05 Solar Satellite Power Systems (SSPS)

AE Geothermal

01 Engineering Research and Development
02 Resource Exploration and Assessment
03 Hydrothermal Technology Applications
04 Advanced Technology Applications
05 Utilization Experiments
06 Environmental Control and Institutional Studies

AF Fusion

01 Magnetic Fusion

01 Confinement Systems
02 Development and Technology
03 Applied Plasma Physics
04 Reactor Projects

AG Fission

01 Uranium Resource Assessment

01 Geologic and Related Investigations
02 Technology Development
03 Supporting Services

02 Fuel Cycle Research and Development

01 Support of Nuclear Fuel Cycle
02 Commercial Waste Management

03 Breeder Reactor

01 Breeder Reactor Studies
02 CRBR Project
03 FFTF Project
04 Breeder Technology
05 Test Facilities

04 Nuclear Research and Applications

01 Water Cooled Breeder Reactors
02 Gas Cooled Thermal Reactors
03 Gas Cooled Fast Breeder Reactors (GCFR)
04 Advanced Convert Reactors
05 Light Water Reactor Technology
06 Technology Development and Special Projects
07 Space Applications
08 Advanced Isotope Separation
09 Nuclear Energy Assessments

05 Light Water Reactor Facilities

06 International Spent Fuel Disposition

AH			Hydroelectric
	01		Low Head Hydroelectric Development
AJ			Biomass (Fuels)
AK			Multi-Resource
	01		Basic Energy Sciences
		01	Nuclear Science
		02	Materials Sciences
		03	Chemical Sciences
		04	Engineering, Mathematical and Geosciences
		05	Advanced Energy Projects
	09		Used Nuclear Equipment Grants (Nonfund)
B			ENERGY SUPPLY - PRODUCTION, DEMONSTRATION AND DISTRIBUTION
BA			Coal
BB			Petroleum
	01		Naval Petroleum and Shale Reserves
BD			Solar
	01		Heating and Cooling Demonstration Program
	02		Federal Buildings Solar Program
	03		Solar Commercialization
BE			Geothermal
BG			Fission
	01		Uranium Enrichment Activities
		01	U-235 Production
		02	Process Development
		03	All Other U-235
BK			Multi-Resource
	01		Electricity
	02		Alternate Fuels Demonstration Program
	03		Federal Leasing
BL			Power Marketing
	01		Alaska Power Administration
	02		Bonneville Power Administration
	03		Reclamation Power Administration
	04		Southwestern Power Administration
	05		Southeastern Power Administration

C			CONSERVATION
C1			Utilities
	01		Electric Energy Systems
	02		Utilities Demonstration
	03		District Heating
	04		Consumer Offices
	05		Rate Reform
C2			Residential
C3			Commercial
C4			Industrial
	01		Industry
	02		Industrial Monitoring
	03		Cogeneration
	04		Industry Energy Conservation
	05		Other Industrial
C5			Transport
	01		Transportation Energy Conservation
		01	Highway Vehicle Systems
		02	Non-Highway Systems
		03	Technology Studies
		04	Electric and Hybrid Power Systems
		05	Technology Implementation
		06	Electric and Hybrid Vehicle RD&D
	02		Mileage Guides
C6			Federal Energy Management
C7			State/Local Programs
C8			Multi-Sector
	01		Energy Storage
	02		Improved Conversion Efficiency
	04		Energy Extension Service
	05		Marketing
	06		Inventors Program Support
	08		Appropriate Technology
D			REGULATION
DB			Petroleum
DC			Gas
	01		Pipeline Regulation
	02		Producer Regulation
DH			Hydro
	01		Water Resources Analysis
	02		Hydroelectric Projects Licenses

DK			Multi-Resource
	01		Petroleum Products and Natural Gas
	02		Compliance
	03		Private Grievances and Redress
	04		Electric Utility Regulation
	05		Compliance and Enforcement
	06		Program Direction - Management
E			EMERGENCY PREPAREDNESS
EB			Petroleum
EK			Multi-Resource
F			ENERGY INFORMATION
G			ENVIRONMENT
GK			Multi-Resource
	01		Environmental Research and Development
		01	Overview and Assessment
		02	Biomedical and Environmental Research
H			BASIC SCIENCES
HK			Multi-Resource
	01		Life Sciences Research and Biomedical Applications
	02		High Energy Physics
	03		Nuclear Physics
J			ATOMIC ENERGY DEFENSE ACTIVITY
JF			Fusion
	01		Inertial Confinement Fusion
JG			Fission
	01		Naval Reactor Development
		01	Submarine Propulsion Reactors
		02	Surface Ship Propulsion Reactors
		03	Supporting Research and Development
JM			Weapons
	01		Weapons Activities
		01	Research and Development
		02	Full-Scale Tests
		03	Production and Surveillance
	02		Intelligence and Arms Control
	03		Special Materials Production
	04		Nuclear Materials Security and Safeguards

K				POLICY AND MANAGEMENT
KK				Multi-Resource
	01			Policy and Program Analysis
	02			General Systems Studies
KN				Other
	01			Program Direction - Management Support
	02			Institutional Relations
		10		Technical Information Services
		20		Industry Relations and Technology
		30		Government Relations
		40		University Programs
			01	Human Resources Development
			02	Manpower and Systems Assessment
			03	University Research and Support Activities
	03			Supporting Activities
	04			International Cooperation in Non-Nuclear Technologies
WN				COST OF WORK FOR OTHERS
	01			Cost of Products Sold
	02			Cost of Services Performed
	03			Cost of UESA Services
	05			Cost of Separative Work - Toll Enriching
	06			Cost of SS Material Sold
	07			Cost of Other Special Products Sold
YN				OTHER COSTS AND CREDITS
ZN				REVENUES
35				CAPITAL EQUIPMENT NOT RELATED TO CONSTRUCTION
39				PLANT ACQUISITION AND CONSTRUCTION
40				COST OF REIMBURSABLE WORK FOR OTHER FEDERAL AGENCIES
50				REVENUE FROM REIMBURSABLE WORK FOR OTHER FEDERAL AGENCIES
80-91				RECONCILING ITEMS AND OTHER CATEGORIES

4. ERDA Budget Estimates, Amended FY 1978*

The following categories were utilized in Authorization Hearings before the House of Representatives for the FY 78 budget. They are based on those shown in 3 above.

a. Conservation Research and Development

i. Electric energy systems and energy storage
ii. End use conservation and technologies to improve efficiency: Industrial energy conservation
Buildings and community design
Transportation energy conservation
Improved conversion efficiency
iii. Energy extension service

b. Fossil Energy Development

i. Coal
ii. Petroleum and natural gas
iii. Oil shale and in situ technology

c. Solar Energy Development

i. Thermal applications
ii. Technology support and utilization
iii. Solar electric
iv. Fuels from biomass

d. Geothermal Energy Development

i. Engineering R&D
ii. Resource exploration and development
iii. Hydrothermal technology applications
iv. Advanced technology applications
v. Utilization experiments
vi. Environmental control and institutional studies

e. Fusion Power Research and Development

i. Magnetic fusion
ii. Laser fusion

f. Basic Energy Sciences

i. Nuclear science
ii. Materials science
iii. Molecular, mathematical, and geoscience
iv. Advanced energy programs

g. High Energy Physics

i. Fermi National Accelerator Laboratory
ii. Alternating Gradient Synchrotron
iii. Zero Gradient Synchrotron
iv. Stanford Linear Accelerator Center

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* U. S. House of Representatives, 95th Congress, 1st Session, Committee on Science and Technology, Hearings, 1978 ERDA Authorization, Volume I.

h. Nuclear Physics

i. Medium energy physics
ii. Heavy ion physics
iii. Nuclear theory

i. Liquid Metal Fast Breeder Reactor

j. Nuclear Research and Applications

i. Water cooled breeder reactors
ii. Gas cooled thermal reactors
iii. Gas cooled fast breeder reactors
iv. Molten salt breeder reactors
v. Technology development and special
vi. Space applications
vii. Advanced isotope separation technology

k. Nuclear Regulatory Commission Safety Facilities

i. Loss of fluid test facility
ii. Plenum fill experimental facility

l. Fuel Cycle Research and Development

i. Uranium resource assessment
ii. Nuclear fuel cycle
iii. Long term isolation or terminal storage
iv. R&D on retrieval storage

m. Uranium Enrichment

i. U-235 production
ii. Process development
iii. All other U-235

n. Environmental Research and Development

i. Overview management
ii. Environmental policy analysis
iii. Integrated assessment
iv. Environmental engineering
v. Standards, safety, and compliance

o. Life Sciences Research and Biomedical Applications

i. General life sciences
ii. Biomedical applications

p. Naval Reactor Development

i. Submarine propulsion reactors
ii. Surface ship propulsion
iii. Supporting research and development

q. Weapons Activities

i. Research and development
ii. Testing of atomic weapons
iii. Special test detection
iv. Production and surveillance

r. Special Materials Production

i. Production
ii. Process development
iii. Waste management (Defense)

s. Nuclear Materials Security and Safeguards

i. Research, development, test, and evaluation
ii. Safeguards analytical laboratory (Support)
iii. Nuclear materials management and safeguards system

t. Nuclear Explosives Applications

i. Storage application development
ii. Technology support

u. Program Direction

v. Institutional Relations

w. Supporting Activities

x. Cost of Work for Others

y. Enrichment Revenues

z. Miscellaneous Revenues

5. <u>ERDA "Uniform Contract or Reporting Guidelines" (UCRG)</u>*

Fossil Fuels (including synfuel)

A1 - Fossil Fuels (general)
A2 - Coal Conversion - Liquefaction
A3 - Coal Conversion - Gasification
A4 - Oil and Gas
A5 - Oil Shale
A6 - Biomass - pyrolysis

Nuclear

B1 - Nuclear (general)
B2 - Fission - Converters
B3 - Fission Breeders
B4 - Fusion Magnetic
B5 - Fusion Laser

Geothermal

C1 - Geothermal (general)
C2 - Hydrothermal
C3 - Geopressurized
C4 - Hot Dry Rock

Solar

D1 - Solar (general)
D2 - Direct Heat/Cool
D3 - Electric
D4 - Ocean, Wind
D5 - Biomass

Conservation

E1 - Conservation (general)
E2 - End Use
E3 - Improved Conversion Efficiency
E4 - Energy Storage

Other

F1 - Multi-Technology
F2 - General (or Basic) Science
F3 - Medical Applications of Nuclear Technology
F4 - Hydroelectric
F5 - Other (identify on the form)

* Energy Research and Development Administration, <u>ERDA Uniform Contractor Reporting Guidelines</u>, January 1977.

6. Scope of Energy R&D Inventory*

PART I. ENERGY SOURCES

A. COAL

1. Exploration, geology, reserves
2. Mining R&D
3. Processing (liquefaction, gasification, desulfurization)
4. Environmental aspects
5. Combustion studies

B. PETROLEUM & NATURAL GAS

1. Exploration, geology, reserves
2. Drilling and production
3. Processing and refining R&D
4. Transporting and storage
5. Combustion studies
6. Environmental aspects

C. OIL SHALES & TAR SANDS

D. NUCLEAR FUELS

1. Exploration, mining, ore processing
2. Uranium enrichment or fuel reprocessing
3. Environmental aspects

E. SOLAR

1. Solar thermal conversion
2. Heating and cooling
3. Wind energy or ocean thermal conversion
4. Photovoltaic conversion
5. Photosynthesis, bioconversion

F. GEOTHERMAL ENERGY

G. SYNTHETIC FUELS (hydrogen, methane, etc.)

H. MISCELLANEOUS

1. Plant and animal by-products
2. Urban and industrial waste
3. Water resources

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* Utilized in the Inventory of Energy Research and Development Conducted by the Oak Ridge National Laboratory for ERDA. Report prepared for the Subcommittee on Energy Research, Development, and Demonstration of the Committee on Science and Technology, U. S. House of Representatives, 94th Congress, 2nd Session, January 1976.

PART II. ELECTRIC POWER

A. ELECTRIC POWER GENERATION

1. Fossil fueled and unspecified
   a. Research and engineering development
   b. Materials and equipment
   c. Cooling systems
   d. Environment - air pollution
   e. Environment - water pollution
   f. Environment - land pollution
   g. Environment - waste product recovery, use, and disposal
2. Fission fueled
   a. Research and engineering development
   b. Materials and equipment
   c. Breeder reactors
   d. All other reactors
   e. Reactor safety studies
   f. Cooling systems
   g. Environment - air pollution
   h. Environment - water pollution
   i. Environment - land pollution
   j. Environment - pollution, radioactive
   k. Environment - waste product recovery, use, and disposal
3. Hydroelectric
4. Nuclear fusion
   a. Plasma properties, production, and heating
   b. Lasers
   c. Confinement
   d. Engineering development
5. Other electric power generation
   a. MHD and EFD
   b. Fuel cells
   c. Thermionic and thermoelectric generators
   d. Power cycles (Rankine, Stirling, Brayton, Combined)

B. ENERGY STORAGE

1. Pumped storage
2. Batteries and storage cells
3. Electrode and electrolyte studies
4. Flywheels

C. ELECTRIC POWER TRANSMISSION AND DISTRIBUTION

1. Undersurface systems (cables, accessories, or superconductivity)
2. Overhead systems (transmission lines, etc.)
3. Stations and substations
4. Relaying, metering, and automation

D. ELECTRIC POWER PLANNING, ENGINEERING, & OPERATIONS

1. Load forecasting
2. System planning, operation, and control
3. Electrical and physical phenomena

PART III. ENERGY USES AND CONSERVATION

A. SPACE HEATING AND COOLING

1. Waste heat utilization
2. Building design

B. LIGHTING, APPLIANCES, AND EQUIPMENT

C. INDUSTRIAL AND MANUFACTURING PROCESSES

D. TRANSPORTATION

1. Air and space
2. Water
3. Ground
    a. Research and engineering development
    b. Internal combustion systems
    c. External combustion systems
    d. Electrical propulsion
    e. Efficiency and fuel economy
4. Environment Aspects
    a. Noise
    b. Exhaust studies
    c. Emissions control

E. AGRICULTURE

PART IV. GENERAL ENERGY-RELATED STUDIES

A. ECONOMICS

1. Supply, demand, forecasting
2. Economic feasibility

B. POLICY, LEGISLATIVE, OR REGULATORY

C. TECHNOLOGY ASSESSMENT

D. SOCIAL AND SOCIO-ECONOMIC ASPECTS

E. PUBLIC INFORMATION AND CONFERENCES

F. OCCUPATIONAL HEALTH HAZARDS

7. Energy Sources and Functions of Federal Energy Information Locator System.*

COAL:
- Exploration
- Resources (reserves)
- Extraction
- Processing
- Transportation
- Organizational and Financial Structure
- Consumption
- Imports and Exports
- Research and Development

ENERGY-RELATED:
- General
- Truck Inventory/Use
- Commodity Transportation
- National Travel
- Farm Expenditures
- Private Electric Utilities--Performance Ratios
- Energy Conservation/Buildings
- Energy Conservation/Industry
- Energy Conservation/Community
- Associated Airline Financial and Operating Data
- Associated Airline Passenger-Travel Data
- Earnings Impacts for Selected Years

GEOTHERMAL:
- Exploration
- Resources (reserves)
- Extraction
- Processing

OIL SHALE:
- Exploration
- Resources (reserves)
- Extraction
- Processing
- Transportation of Syncrude

ELECTRICITY:
- Production
- Distribution
- Consumption
- Organizational and Financial Structure
- Research and Development

NATURAL GAS:
- Exploration
- Resources (reserves)
- Production
- Storage
- Distribution
- Imports and Exports
- Processing
- Consumption
- Organizational and Financial Structure
- Research and Development

NUCLEAR:
- Exploration
- Resources (reserves)
- Extraction (mining)
- Transportation
- Milling
- Uranium Hexaflouride Production
- Enrichment
- Fabrication
- Storage
- Imports and Exports
- Reprocessing
- Waste Management
- Research and Development
- Organizational and Financial Structure
- Reactor Operations
- Licensing
- Uranium Sales

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* Federal Energy Administration, National Energy Information Center, Federal Energy Information Locator System, FEA/B-76/492, Washington, D.C., November 30, 1976.

ORGANIC WASTE:
- Research and Development

PETROLEUM:
- Exploration
- Resources (reserves)
- Production
- Storage (crude)
- Transportation (crude)
- Organizational and Financial Structure
- Imports and Exports
- Research and Development
- Purchases by Type

SOLAR:
- Resources (system)

PETROLEUM PRODUCTS:
- Refining
- Product Storage
- Transportation
- Imports and Exports
- Consumption
- Organizational and Financial Structure
- Research and Development
- Petrochemical Operations
- Sales by Type
- Refining Outputs
- Purchases by Type

TAR SANDS:
- Exploration
- Resources (system)
- Extraction
- Processing
- Transportation
- Organizational and Financial Structure

C. CATEGORIES OF MANPOWER (e.g. DOE Intramural RD&D, Other Federal Supported Energy, etc.)

Shown in Chapter II, Section B

D. OCCUPATIONAL GROUPS AND SPECIALTIES

The following list is based on the Standard Occupational Classification (being developed under the aegis of OMB).* It is a broad general listing of occupations, similar in content to those generally used in other programs, for example, the Dictionary of Occupational Titles, Census Occupational Classification System, and those used in manpower surveys such as those of NSF and BLS.

1. Engineers and Scientists (including college professors and instructors)

   a. Engineers

Aeronautical	Metallurgical, materials
Agricultural	Mechanical
Ceramic	Mining
Chemical	Nuclear
Civil, sanitary	Petroleum
Geological	Other engineers
Industrial	

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* Executive Office of the President, Office of Management and Budget, Standard Occupational Classification Manual (Draft), 1976.

b. Environmental Scientists

Atmospheric, meterologists
Earth scientists, geologists, geophysicists
Oceanographers

c. Physical Scientists

Chemists	Physicists and astronomers
Metallurgists	Other physical scientists

d. Mathematicians and Statisticians

Actuaries	Operations research analysts
Mathematicians	Statisticians

e. Life Scientists

Agricultural (including foresters and conservationists)
Biological scientists -
(anatomists, bacteriologists, botanists, entomologists, geneticists, microbiologists, plant pathologists, soil scientists, zoologists, etc.)
Biochemists
Biophysicists
Medical scientists

f. Social Scientists

Economists	Sociologists and anthropologists
Psychologists	Other social scientists

g. Health Professionals

Dentists	Physicians and surgeons
Nurses	Other health professions
Pharmacists	

h. Architects

2. Technicians and Technologists

a. Draftsmen and designers - tool, mechanical architectural and similar types
b. Surveyors
c. Technicians (medical, dental, life sciences, electrical and electronic, mechanical, construction, engineering, physical sciences, social sciences)

3. Administrators and Managers, technical

a. Dean or department head in college or university
b. Head of research, development, or demonstration laboratory or facility
c. Manager of gas plants, electric utilities, etc.
d. Superintendent of drilling and production, pipelines, etc.
e. Other scientific and technical administrators and managers

4. Skilled Craftsmen*

a. Construction craftsmen

Brick stonemason
Bulldozer operator
Carpenter
Cement/concrete finisher
Electrician
Excavating/grading machine operator
Painter
Plumber pipefitter
Structural metal craft

b. Other craftsmen

Boilermaker
Craneman derrickman
Electric power lineman
Inspector
Machinist
Mechanical repairman
Millwright
Power station operator
Sheetmetal worker
Stationary engineer

c. Operatives

Asbestos worker
Blaster powderman
Driller earth
Mine operative not elsewhere classified
Oiler greaser
Stationary fireman
Transport equipment operator
Welder flamecutter

d. Foreman, relevant occupations and industries

The review of operations for occupations unique to energy did not reveal any unexpected specialties and practically all can be subsumed under the several categories shown above. Among the more unusual specialties were the following:

Engineers
Geological
Corrosion
Combustion
Environmental

Chemists
Corrosion
Surface
Atmospheric
Solid state
Electrochemist

Physicists
Plasma
Optical
Atmospheric

Other scientists
Epidemiologist
Aquatic ecologist
Microbiological ecologist
Thermodynamicist
Physical metallurgist
Toxicologist

E. FIELDS OF DEGREES, OTHER AWARDS AND ENROLLMENTS

Full detail of the taxonomy is shown in those broad areas within which some categories are relevant to energy RD&D--maybe only a single item in some cases. Group titles with little likely relevance to energy RD&D are shown for information only (and to complete the full taxonomy of instructional programs) and no detail is given (e.g., area studies, education, fine and applied arts, etc.)

* Based on lists used in Project Independence Labor Report and on list used by ERDA in GOCO Contract Manpower Reports.

1. CONVENTIONAL ACADEMIC SUBDIVISIONS OF KNOWLEDGE AND TRAINING *

0100 AGRICULTURE and NATURAL RESOURCES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with the production of food and management of natural fiber, plant, forest, and wildlife resources.

0101 Agriculture, general
0102 Agronomy (field crops, and crop management)
0103 Soils science (management and conservation)
0104 Animal science (husbandry)
0105 Dairy science (husbandry)
0106 Poultry science
0107 Fish, game, and wildlife management
0108 Horticulture (fruit and vegetable production)
0109 Ornamental horticulture (floriculture, nursery science)
0110 Agricultural and farm management
0111 Agricultural economics
0112 Agricultural business
0113 Food science and technology
0114 Forestry
0115 Natural resources management
0116 Agriculture and forestry technologies (baccalaureate and higher programs)
0117 Range management
0199 Other, specify

0200 ARCHITECTURE and ENVIRONMENTAL DESIGN

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with training for a profession in designing buildings, communities, parks, and other manmade aspects of the physiosocial environment.

0201 Environmental design, general
0202 Architecture
0203 Interior design
0204 Landscape architecture
0205 Urban architecture
0206 City, community, and regional planning
0299. Other, specify

0300 AREA STUDIES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with programs designed to study cultures indigenous to specific geographic regions.

0301 Asian studies, general
0302 East Asian studies
0303 South Asian (India, etc.) studies
0304 Southeast Asian studies
0305 African studies
0306 Islamic studies
0307 Russian and Slavic studies
0308 Latin American studies
0309 Middle Eastern studies
0310 European studies, general
0311 Eastern European studies
0312 West European studies
0313 American studies
0314 Pacific area studies
0399 Other, specify

0400 BIOLOGICAL SCIENCES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with the science of life or living matter in all its forms and phenomena especially with regard to the origin, growth, reproduction, and structure of life forms.

0401 Biology, general
0402 Botany, general
0403 Bacteriology
0404 Plant pathology
0405 Plant pharmacology
0406 Plant physiology
0407 Zoology, general
0408 Pathology, human and animal
0409 Pharmacology, human and animal
0410 Physiology, human and animal
0411 Microbiology
0412 Anatomy
0413 Histology
0414 Biochemistry
0415 Biophysics
0416 Molecular biology
0417 Cell biology (cytology, cell physiology)
0418 Marine biology
0419 Biometrics and biostatistics
0420 Ecology
0421 Entomology
0422 Genetics
0423 Radiobiology
0424 Nutrition, scientific (excludes nutrition in home economics and dietetics)
0425 Neurosciences
0426 Toxicology
0427 Embryology
0499 Other, specify

0500 BUSINESS and MANAGEMENT

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. related to the organization, operation, administration, and control of private and public organizations.

0501 Business and commerce, general
0502 Accounting
0503 Business statistics
0504 Banking and finance
0505 Investments and securities
0506 Business management and administration
0507 Operations research
0508 Hotel and restaurant management
0509 Marketing and purchasing
0510 Transportation and public utilities
0511 Real estate
0512 Insurance
0513 International business
0514 Secretarial studies (baccalaureate and higher programs)
0515 Personnel management
0516 Labor and industrial relations
0517 Business economics
0599 Other, specify

0600 COMMUNICATIONS

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. related to collection, preparation, and presentation of ideas and information intended for popular consumption through mass media.

0601 Communications, general
0602 Journalism (printed media)
0603 Radio/television
0604 Advertising
0605 Communication media (use of videotape, films, etc., oriented specifically toward radio/television)
0699 Other, specify

*Department of Health, Education, and Welfare, National Center for Education Statistics, A Taxonomy of Instructional Programs in Higher Education, OE-50064, Washington, D.C. 1970.

0700 COMPUTER and INFORMATION SCIENCES

Subject field designations which characterize students, faculty, facilities, degree programs, course work, research projects, etc. having to do with the design, development, and application of computer capabilities to data storage and manipulation and related computational procedures.

0701 Computer and information sciences, general
0702 Information sciences and systems
0703 Data processing
0704 Computer programming
0705 Systems analysis
0799 Other, specify

0800 EDUCATION

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. related to administration and control of educational organizations and institutions and subjects related to instruction and services both within and outside of such formal organizations.

0801 Education, general
0802 Elementary education, general
0803 Secondary education, general
0804 Junior high school education
0805 Higher education, general
0806 Junior and community college education
0807 Adult and continuing education
0808 Special education, general
0809 Administration of special education
0810 Education of the mentally retarded
0811 Education of the gifted
0812 Education of the deaf
0813 Education of the culturally disadvantaged
0814 Education of the visually handicapped
0815 Speech correction
0816 Education of the emotionally disturbed
0817 Remedial education
0818 Special learning disabilities
0819 Education of the physically handicapped
0820 Education of the multiple handicapped
0821 Social foundations (history and philosophy of education)
0822 Educational psychology (include learning theory)
0823 Pre-elementary education (kindergarten)
0824 Educational statistics and research
0825 Educational testing, evaluation and measurement
0826 Student personnel (counseling and guidance)
0827 Educational administration
0828 Educational supervision
0829 Curriculum and instruction
0830 Reading education (methodology and theory)
0831 Art education (methodology and theory)
0832 Music education (methodology and theory)
0833 Mathematics education (methodology and theory)
0834 Science education (methodology and theory)
0835 Physical education
0836 Driver and safety education
0837 Health education (include family life education)
0838 Business, commerce, and distributive education
0839 Industrial arts, vocational, and technical education
0899 Other, specify

0900 ENGINEERING

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with the practical application of basic scientific knowledge to the design, production, and operation of systems intended to facilitate man's control and use of his natural environment.

0901 Engineering, general
0902 Aerospace, aeronautical and astronautical engineering
0903 Agricultural engineering
0904 Architectural engineering
0905 Bioengineering and biomedical engineering
0906 Chemical engineering (include petroleum refining)
0907 Petroleum engineering (exclude petroleum refining)
0908 Civil, construction, and transportation engineering
0909 Electrical, electronics, and communications engineering
0910 Mechanical engineering
0911 Geological engineering
0912 Geophysical engineering
0913 Industrial and management engineering
0914 Metallurgical engineering
0915 Materials engineering
0916 Ceramic engineering
0917 Textile engineering
0918 Mining and mineral engineering
0919 Engineering physics
0920 Nuclear engineering
0921 Engineering mechanics
0922 Environmental and sanitary engineering
0923 Naval architecture and marine engineering
0924 Ocean engineering
0925 Engineering technologies (baccalaureate and higher programs)
0999 Other, specify

1000 FINE and APPLIED ARTS

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with the creation and appreciation of the diverse modes of communicating ideas and emotions by means of stylized, visual, and non-visual representations and symbols.

1001 Fine arts, general
1002 Art (painting, drawing, sculpture)
1003 Art history and appreciation
1004 Music (performing, composition, theory)
1005 Music (liberal arts program)
1006 Music history and appreciation (musicology)
1007 Dramatic arts
1008 Dance
1009 Applied design (ceramics, weaving, textile design, fashion design, jewelry, metalsmithing, interior decoration, commercial art)
1010 Cinematography
1011 Photography
1099 Other, specify

1100 FOREIGN LANGUAGES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. related to mastery of a language other than English or related to the study of a foreign culture through exploration of the literature of that culture as expressed in the vernacular language.

1101 Foreign languages, general (includes concentration on more than one foreign language without major emphasis on one language)
1102 French
1103 German
1104 Italian
1105 Spanish
1106 Russian
1107 Chinese

1108 Japanese
1109 Latin
1110 Greek, classical
1111 Hebrew
1112 Arabic
1113 Indian (Asiatic)
1114 Scandinavian languages
1115 Slavic languages (other than Russian)
1116 African languages (non-Semitic)
1199 Other, specify

1200 HEALTH PROFESSIONS

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with the maintenance and restoration of physical and mental health.

1201 Health professions, general
1202 Hospital and health care administration
1203 Nursing (baccalaureate and higher programs)
1204 Dentistry, D.D.S. or D.M.D. degree
1205 Dental specialties (work beyond first-professional degree, D.D.S. or D.M.D.)
1206 Medicine, M.D. degree
1207 Medical specialties (work beyond first-professional degree, M.D.)
1208 Occupational therapy
1209 Optometry
1210 Osteopathic medicine, D.O. degree
1211 Pharmacy
1212 Physical therapy
1213 Dental hygiene (baccalaureate and higher programs)
1214 Public health
1215 Medical record librarianship
1216 Podiatry (Pod.D. or D. P.) or podiatric medicine (D.P.M.)
1217 Biomedical communication
1218 Veterinary medicine (D.V.M. degree)
1219 Veterinary medicine specialties (work beyond first-professional degree, D.V.M.)
1220 Speech pathology and audiology
1221 Chiropractic
1222 Clinical social work (medical and psychiatric and specialized rehabilitation services)
1223 Medical laboratory technologies (baccalaureate and higher programs)
1224 Dental technologies (baccalaureate and higher programs)
1225 Radiologic technologies (baccalaureate and higher programs)
1299 Other, specify

1300 HOME ECONOMICS

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with the theory and practice of family and home care including the science of foods, home decoration and management, and child care.

1301 Home economics, general
1302 Home decoration and home equipment
1303 Clothing and textiles
1304 Consumer economics and home management
1305 Family relations and child development
1306 Foods and nutrition (include dietetics)
1307 Institutional management and cafeteria management
1399 Other, specify

1400 LAW

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with instruction in the legal customs, practices, and rules of society and states for the purpose of pursuing a career in jurisprudence.

1401 Law, general
1499 Other, specify

1500 LETTERS

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with English language and literature and value systems related to ancient and modern cultures.

1501 English, general
1502 Literature, English
1503 Comparative literature
1504 Classics
1505 Linguistics (include phonetics, semantics, and philology)
1506 Speech, debate, and forensic science (rhetoric and public address)
1507 Creative writing
1508 Teaching of English as a foreign language
1509 Philosophy
1510 Religious studies (exclude theological professions)
1599 Other, specify

1600 LIBRARY SCIENCE

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with instruction in the professional skills required to organize collections of books and related materials and the training necessary for providing services related to them.

1601 Library science, general
1699 Other, specify

1700 MATHEMATICS

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with the science of numbers and space configurations and their operations, measurement, relationships, and abstractions.

1701 Mathematics, general
1702 Statistics, mathematical and theoretical
1703 Applied mathematics
1799 Other, specify

1800 MILITARY SCIENCES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with techniques and skills unique to the pursuit of a professional career as a military officer.

1801 Military science (Army)
1802 Naval science (Navy, Marines)
1803 Aerospace science (Air Force)
1899 Other, specify

1900 PHYSICAL SCIENCES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with the basic nature of matter, energy, and associated phenomena.

1901 Physical sciences, general
1902 Physics, general (exclude biophysics)
1903 Molecular physics
1904 Nuclear physics

1905 Chemistry, general (exclude biochemistry)
1906 Inorganic chemistry
1907 Organic chemistry
1908 Physical chemistry
1909 Analytical chemistry
1910 Pharmaceutical chemistry
1911 Astronomy
1912 Astrophysics
1913 Atmospheric sciences and meteorology
1914 Geology
1915 Geochemistry
1916 Geophysics and seismology
1917 Earth sciences, general
1918 Paleontology
1919 Oceanography
1920 Metallurgy
1999 Other, specify

2000 PSYCHOLOGY

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with behavioral and mental processes.

2001 Psychology, general
2002 Experimental psychology (animal and human)
2003 Clinical psychology
2004 Psychology for counseling
2005 Social psychology
2006 Psychometrics
2007 Statistics in psychology
2008 Industrial psychology
2009 Developmental psychology
2010 Physiological psychology
2099 Other, specify

2100 PUBLIC AFFAIRS and SERVICES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. related to developing and improving competencies in the management and operation of governmental agencies.

2101 Community services, general
2102 Public administration
2103 Parks and recreation management
2104 Social work and helping services (other than clinical social work)
2105 Law enforcement and corrections (baccalaureate and higher programs)
2106 International public service (other than diplomatic service)
2199 Other, specify

2200 SOCIAL SCIENCES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. having to do with all aspects of the past and present activities, conduct, interactions, and organizations of humans.

2201 Social sciences, general
2202 Anthropology
2203 Archaeology
2204 Economics
2205 History
2206 Geography
2207 Political science and government
2208 Sociology
2209 Criminology
2210 International relations
2211 Afro-American (black culture) studies
2212 American Indian cultural studies
2213 Mexican-American cultural studies
2214 Urban studies
2215 Demography
2299 Other, specify

2300 THEOLOGY

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. related to preparation and training for a religious vocation.

2301 Theological professions, general
2302 Religious music
2303 Biblical languages
2304 Religious education
2399 Other, specify

4900 INTERDISCIPLINARY STUDIES

Subject field designations which characterize students, faculty, facilities, degree programs, research projects, etc. involving more than one major discipline without primary concentration in any one area.

4901 General liberal arts and sciences
4902 Biological and physical sciences
4903 Humanities and social sciences
4904 Engineering and other disciplines
4999 Other, specify

2. TECHNOLOGICAL AND OCCUPATIONAL CURRICULUMS LEADING TO ASSOCIATE DEGREES AND OTHER AWARDS BELOW THE BACCALAUREATE

5000 BUSINESS and COMMERCE TECHNOLOGIES

Subject field designations which characterize students, faculty, facilities, degree and certificate programs, etc. specifically associated with development of skills required for commercial, business, or secretarial occupations at the semiprofessional level. Two years of preparation beyond high school are usually sufficient for entrance into these occupational fields.

5001 Business and commerce technologies, general
5002 Accounting technologies
5003 Banking and finance technologies
5004 Marketing, distribution, purchasing, business, and industrial management technologies
5005 Secretarial technologies (include office machines training)
5006 Personal service technologies (stewardess, cosmetologist, etc.)
5007 Photography technologies
5008 Communications and broadcasting technologies (radio/television, newspapers)
5009 Printing and lithography technologies
5010 Hotel and restaurant management technologies
5011 Transportation and public utility technologies
5012 Applied arts, graphic arts, and fine arts technologies (include advertising design)
5099 Other, specify

5100 DATA PROCESSING TECHNOLOGIES

Subject field designations which characterize students, faculty, facilities, degree and certificate programs, etc. specifically associated with development of skills required for data processing or related occupations at the *semiprofessional level. Two years of preparation beyond high school are usually sufficient for entrance into these occupational fields.*

5101 Data processing technologies, general
5102 Key punch operator and other input preparation technologies
5103 Computer programmer technologies
5104 Computer operator and peripheral equipment operation technologies
5105 Data processing equipment maintenance technologies
5199 Other, specify

5200 HEALTH SERVICES and PARAMEDICAL TECHNOLOGIES

Subject field designations which characterize students, faculty, facilities, degree and certificate programs, etc. specifically associated with development of skills required for health service related occupations at the semiprofessional level. Two years of preparation beyond high school are usually sufficient for entrance into these occupational fields.

5201 Health services assistant technologies, general
5202 Dental assistant technologies
5203 Dental hygiene technologies
5204 Dental laboratory technologies
5205 Medical or biological laboratory assistant technologies
5206 Animal laboratory assistant technologies
5207 Radiologic technologies (X-ray, etc.)
5208 Nursing, R.N. (less than 4-year program)
5209 Nursing, practical (L.P.N. or L.V.N.—less than 4-year program)
5210 Occupational therapy technologies
5211 Surgical technologies
5212 Optical technologies (include ocular care, ophthalmic, optometric technologies)
5213 Medical record technologies
5214 Medical assistant and medical office assistant technologies
5215 Inhalation therapy technologies
5216 Psychiatric technologies (include mental health aide programs)
5217 Electro diagnostic technologies (include E.K.G., E.E.G., etc.)
5218 Institutional management technologies (rest home, etc.)
5219 Physical therapy technologies
5299 Other, specify

5300 MECHANICAL and ENGINEERING TECHNOLOGIES

Subject field designations which characterize students, faculty, facilities, degree and certificate programs, etc. specifically associated with development of skills required for mechanical and engineering related occupations at the semiprofessional level. Two years of preparation beyond high school are usually sufficient for entrance into these occupational fields.

5301 Mechanical and engineering technologies, general
5302 Aeronautical and aviation technologies
5303 Engineering graphics (tool and machine drafting and design)
5304 Architectural drafting technologies
5305 Chemical technologies (include plastics)
5306 Automotive technologies
5307 Diesel technologies
5308 Welding technologies
5309 Civil technologies (surveying, photogrammetry, etc.)
5310 Electronics and machine technologies (television, appliance, office machine repair, etc.)
5311 Electromechanical technologies
5312 Industrial technologies
5313 Textile technologies
5314 Instrumentation technologies
5315 Mechanical technologies
5316 Nuclear technologies
5317 Construction and building technologies (carpentry, electrical work, plumbing, sheet metal, air conditioning, heating, etc.)
5399 Other, specify

5400 NATURAL SCIENCE TECHNOLOGIES

Subject field designations which characterize students, faculty, facilities, degree and certificate programs, etc. specifically associated with development of skills required for natural science related occupations at the semiprofessional level. Two years of preparation beyond high school are usually sufficient for entrance into these occupational fields.

5401 Natural science technologies, general
5402 Agriculture technologies (include horticulture)
5403 Forestry and wildlife technologies (include fisheries)
5404 Food services technologies
5405 Home economics technologies
5406 Marine and oceanographic technologies
5407 Laboratory technologies, general
5408 Sanitation and public health inspection technologies (environmental health technologies)
5499 Other, specify

5500 PUBLIC SERVICE RELATED TECHNOLOGIES

Subject field designations which characterize students, faculty, facilities, degree and certificate programs etc. specifically associated with development of skills required for public service related occupations at the semiprofessional level. Two years of preparation beyond high school are usually sufficient for entrance into these occupational fields.

5501 Public service technologies, general
5502 Bible study or religion-related occupations
5503 Education technologies (teacher aide and 2-year teacher training programs)
5504 Library assistant technologies
5505 Police, law enforcement, corrections technologies
5506 Recreation and social work related technologies
5507 Fire control technology
5508 Public administration and management technologies
5599 Other, specify

3. SPECIALTIES OF DOCTORAL DEGREES

MATHEMATICS
000 — Algebra
010 — Analysis & Functional Analysis
020 — Geometry
030 — Logic
040 — Number Theory
050 — Probability, Math. Statistics (see also 544, 670, 725, 727, 920)
060 — Topology
080 — Computing Theory & Practice
082 — Operations Research (see also 478)
085 — Applied Mathematics
098 — Mathematics, General
099 — Mathematics, Other*

ASTRONOMY
101 — Astronomy
102 — Astrophysics

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

CHEMISTRY
200 — Analytical
210 — Inorganic
220 — Organic
230 — Nuclear
240 — Physical
250 — Theoretical
260 — Agricultural & Food
270 — Pharmaceutical
275 — Polymer
298 — Chemistry, General
299 — Chemistry, Other*

EARTH 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 Physics and Chemistry
382 — Atmospheric Dynamics
383 — Atmospheric Sciences, Other*
391 — Applied Geol., Geol. Engr., Econ. Geol.
395 — Fuel Tech., Petrol. Engr. (see also 479)
398 — Earth Sciences, General
399 — Earth Sciences, Other*

ENGINEERING
400 — Aeronautical & Astronautical
410 — Agricultural
415 — Biomedical
420 — Civil
430 — Chemical
435 — Ceramic
437 — Computer
440 — Electrical
445 — Electronics
450 — Industrial
455 — Nuclear
460 — Engineering Mechanics
465 — Engineering Physics
470 — Mechanical
475 — Metallurgy & Phys. Met. Engr.
476 — Systems Design, Systems Science
478 — Operations Research (see also 082)
479 — Fuel Tech., Petrol. Engr. (see also 395)
480 — Sanitary
486 — Mining
497 — Materials Science
498 — Engineering, General
499 — Engineering, Other*

ENVIRONMENTAL SCIENCES
589 — Environmental Sciences*

AGRICULTURAL SCIENCES
500 — Agronomy
501 — Agricultural Economics
502 — Animal Husbandry
503 — Food Science & Technology
504 — Fish & Wildlife
505 — Forestry
506 — Horticulture
507 — Soils & Soil Science
510 — Animal Sciences
511 — Phytopathology
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
542 — Biophysics
544 — Biometrics, Biostatistics (see also 050, 670, 725, 727, 920)
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
576 — Nutrition and/or Dietetics
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 050, 544, 725, 727, 920)
680 — Social
698 — Psychology, General
699 — Psychology, Other*

SOCIAL SCIENCES
700 — Anthropology
708 — Communications*
710 — Sociology
720 — Economics (see also 501)
725 — Econometrics (see also 050, 544, 670, 727, 920)
727 — Statistics (see also 050, 544, 670, 725, 920)
740 — Geography
745 — Area Studies*
751 — Political Science
752 — Public Administration
755 — International Relations
770 — Urban & Reg. Planning
798 — Social Sciences, General
799 — Social Sciences, Other*

ARTS & HUMANITIES
801 — Art, Applied
802 — Art, History & Criticism
804 — History, American
805 — History, European
806 — History, Other*
807 — History & Philosophy of Science
808 — American Studies
830 — Music
831 — Speech as a Dramatic Art (see also 885)
832 — Archeology
833 — Religion (see also 881)
834 — Philosophy
835 — Linguistics
836 — Comparative Literature
878 — Arts & Humanities, General
879 — Arts & Humanities, Other*

LANGUAGES & LITERATURE
811 — American
812 — English
821 — German
822 — Russian
823 — French
824 — Spanish & Portuguese
826 — Italian
827 — Classical*
829 — Other Languages*

EDUCATION
900 — Foundations: Social, Philosoph.
910 — Educational Psychology
908 — Elementary Educ., General
909 — Secondary Educ., General
918 — Higher Education
919 — Adult Educ. & Extension Educ.
920 — Educ. Meas. & Stat.
929 — Curriculum & Instruction
930 — Educ. Admin. & Superv.
940 — Guid., Couns., & Student Pers.
950 — Special Education (Gifted, Handicapped, etc.)
960 — Audio-Visual Media

TEACHING FIELDS
970 — Agriculture Educ.
972 — Art Educ.
974 — Business Educ.
976 — English Educ.
978 — Foreign Languages Educ.
980 — Home Economics Educ.
982 — Industrial Arts Educ.
984 — Mathematics Educ.
986 — Music Educ.
988 — Phys. Ed., Health, & Recreation
989 — Reading Education
990 — Science Educ.
992 — Social Science Educ.
993 — Speech Education
994 — Vocational Educ.
996 — Other Teaching Fields*

998 — Education, General
999 — Education, Other*

OTHER PROFESSIONAL FIELDS
881 — Theology (see also 833)
882 — Business Administration
883 — Home Economics
884 — Journalism
885 — Speech & Hearing Sciences (see also 831)
886 — Law, Jurisprudence
887 — Social Work
891 — Library & Archival Science
897 — Professional Field, Other*

899 — OTHER FIELDS*

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

National Research Council, Summary Report 1976 Doctorate Recipients From United States Universities, March 1977.

F. INDUSTRIAL CATEGORIES

Industrial categories in nearly all cases are based on the taxonomy established in the Standard Industrial Classification Manual issued by the Office of Management and Budget.* In Chapter II, Section G, industrial coding is discussed and a list of basic energy industries is provided. The following are other examples of classifications of other "energy industries."

1. Indirect Energy Industries (as identified by Folk and associates**)

SIC	Industry
281	Industrial chemicals
1623	Heavy construction contractors except highway and street
1629	Heavy construction, nec.
3293	Gaskets, packing, and asbestos insulation for boilers
3317	Oil country tubular goods
3433	Heating equipment, except electric
3443	Fabricated plate work (boiler shops)
345	Screw machine products, etc.
3494	Pipe fittings, flanges and valves
3511	Turbines and steam engines
3531	Construction equipment
3532	Mining equipment
3533	Oil field equipment
3534	Elevators and moving stairways
3536	Cranes and hoists
3535	Conveyors and conveying equipment
3561	Pumps and compressors
3568	Mechanical power transmission equipment, nec.
3567	Industrial process furnaces and ovens
3612	Power, distribution, and specialty transformers
3613	Switchgear
3621	Motors and generators
3623	Welding apparatus
3811	Mechanical controls and instruments
3822	Automatic temperature controls
7391	Research and development laboratories
8911	Architectural and engineering services
8922	Noncommercial educational, scientific, and research organizations
9631	Regulatory agencies

* Executive Office of the President, Office of Management and Budget, Standard Industrial Classification Manual, 1972.

** Hugh Folk, *op. cit.*, p. 5.

2. Energy-Related Industries*

Based on the use of an input-output coefficient cutoff of .01, the following list of industries "related" to each of several major energy industries was prepared.

COAL MINING

Related Industries
- Coal mining
- Crude petroleum and natural gas
- Maintenance and repair construction (all other)
- Industrial organic and inorganic chemicals
- Miscellaneous chemical products
- Petroleum refining and other products
- Reclaimed rubber and miscellaneous rubber products
- Blast furnaces and basic steel products
- Screw machine products and bolts, nuts, rivets and washers
- Construction machinery
- Mining machinery
- Railroads and related services
- Electric utilities
- Wholesale trade
- Real estate
- Miscellaneous business services
- Miscellaneous professional services

CRUDE PETROLEUM AND NATURAL GAS

Related Industries
- Crude petroleum and natural gas
- Maintenance and repair construction (all other)
- Industrial inorganic and organic chemicals
- Blast furnaces and basic steel products
- Electric utilities
- Wholesale trade
- Retail trade
- Real estate
- Miscellaneous business services
- Miscellaneous professional services
- Transferred imports
- Business travel, entertainment and gifts

PETROLEUM REFINING AND RELATED PRODUCTS

Related Industries
- Crude petroleum and natural gas
- Maintenance and repair construction (all other)
- Industrial inorganic and organic chemicals
- Petroleum refining and related products

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* American Society for Engineering Education, A Proposed Plan for Education and Training in Nonnuclear and Nuclear Energy Technologies, ERDA 76-133, February 1977.

PETROLEUM REFINING AND RELATED PRODUCTS (continued)

- Blast furnaces and basic steel products
- Motor freight transportation and warehousing
- Water transportation
- Pipeline transportation
- Electric utilities
- Gas utilities
- Wholesale trade
- Banking
- Real estate
- Miscellaneous business services
- Advertising
- Miscellaneous professional services
- Transferred imports

ELECTRIC UTILITIES

Related Industries

- Coal Mining
- Crude petroleum and natural gas
- Maintenance and repair construction (all other)
- Petroleum refining and related products
- Railroads and related services
- Motor freight transport and warehousing
- Electric utilities
- Gas utilities
- Real estate
- Miscellaneous business services
- Federal electric utilities
- State and local electric utilities

GAS UTILITIES

Related Industries

- Crude petroleum and natural gas
- Maintenance and repair construction (all other)
- Gas utilities
- Real estate
- Miscellaneous business services
- Other state and local government enterprises
- Transferred imports

APPENDIX B*

DATA SOURCES RELEVANT TO ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION MANPOWER

Table Of Contents

* The data sources listed in this Appendix are, in general, arranged according to agency publishing the principal report. In a number of cases more than one agency is involved in a survey or report. This is brought out in the description of the data source.

DSE 1 - Engineer/Scientist Demand Index

EMC 1 - Professional Income of Engineers

EMC 2 - Survey of Placement of Engineering Graduates

ERDA 1 - Report of Contractor Hours and Earnings

ERDA 2 - Report of Contractor Employment and Turnover

ERDA 3 - Nuclear Engineering Enrollments and Degrees

ERDA 4 - Radiation Protection Enrollment Degree Survey

ERDA 5 - Survey of Occupational Employment in Nuclear or Nuclear Related Energy Activities

ERDA 6 - Nuclear-Related Technician Manpower

ERDA 7 - Industrial Training

ERDA 8 - Energy Related Technology Programs AACJC

ERDA 9 - Comparison of Compensation Paid Scientists and Engineers in R&D

ETA 1 - Employment Service Applicants File

ETA 2 - Projecting Employment Requirements for Energy Development and Expansion in Federal Region VIII

ETA 3 - Employment Service Job Openings
(a) Job Bank Openings Summary
(b) Occupations in Demand
(c) Job Bank - Frequently Listed Openings

ETA 4 - Apprenticeship Statistics

ICC 1. - Annual Reports of Interstate Carriers

INS 1 - Beneficiaries of Occupational Preference and other Immigrants admitted, by Occupation

KAI 1 - Coal Manpower Projections, 1980

NCES 1 - Earned Degrees Conferred (HEGIS)

NCES 2 - Students Enrolled for Advanced Degrees (HEGIS)

NCES 3 - Associate Degrees and Other Formal Awards Below the Baccalaureate (HEGIS)

NCES 4 - Upper Division Enrollment by Degree Field (HEGIS)

NCES 5 - Survey of Recent College Graduates

NRC 1 - Survey of Earned Doctorates

NRC 2 - Survey of Doctoral Scientists and Engineers

NSF 1 - Federal Funds for Research, Development and other Scientific Activities

NSF 2 - Federal R&D Funding by Function

NSF 3 - Energy R&D in Federal Installations

NSF 4 - Research and Development in Industry

NSF 5 - Research and Development in State Government Agencies

NSF 6 - Expenditures for Scientific Activities at Universities and Colleges

NSF 7 - Federal Support of Research in Universities and Non-profit Organizations

NSF 8 - Research and Development Spending by Non-Profit Organizations

NSF 9 - National Patterns of R&D Resources: Funds and Manpower

NSF 10 - Federal Employment of Scientific and Technical Personnel

NSF 11 - Industrial Employment of Scientists and Engineers

NSF 12 - Scientists and Engineers Employed by Universities and Colleges

NSF 13 - Graduate Science Student Support and Post Doctorals

NSF 14 - 1972 Professional, Technical and Scientific Manpower Survey (Post Censal Survey.)

NSF 15 - National Sample of Scientists and Engineers

NSF 16 - Immigration of Engineers and Scientists

NSF 17 - R&D in Local Government

NSF 18 - New Entrants Survey of Recent College Graduates

NSF 19 - Immigrant Scientists and Engineers, A Study of Characteristics and Attitudes

NWU 1 - The Endicott Report: Trends in Employment of College and University Graduates in Business and Industry

OECD 1 - International Measures of Research & Development

ORNL 1 - Inventory of Energy Research and Development

PSU 1 - The Bituminous Coal Industry: A Forecast - Manpower-Government Policy - Technology

SMC 1 - Salaries of Scientists, Engineers and Technicians - A Summary of Salary Surveys

UCAL 1 - The American Freshman: National Norms

JUNIOR YEAR ENROLLMENT

Agency: American Council on Education for National Science Foundation
Unit: Higher Education Panel

Description:

Content: One of the surveys conducted through the Higher Education Panel (HEP) operated by the American Council on Education (ACE) for the National Science Foundation (NSF). Survey was conducted in January 1975 of enrollment in the junior year by field for Fall 1973 and Fall 1974. Data are classified by field and type of institution control.

Coverage, Survey Method, Sources, Sample: The HEP was created in 1971 to conduct quick-turnaround surveys on policy issues in higher education. A sample of 543 institutions (offering at least the baccalaureate) are included in the Panel. Response rate was 91% for this survey. Survey was conducted in 1972 and 1973 also.

Reference Date: Fall

Frequency: Periodic

When Available: Several months after survey

Classifications: Taxonomy of National Center for Education Statistics (NCES) as revised by NSF.

Forms and Reports: Major Field Enrollment of Junior-Year Students, 1973 & 1974.

Evaluation Commentary: Surveys provide a quick look at career interest at junior year period of college students and means of estimating future graduations by field. Survey will be conducted periodically upon experience of need by sponsors. NCES survey of upper division enrollment could affect such plans if it is continued.

NUCLEAR EMPLOYMENT OUTLOOK

Agency: American Nuclear Society

Description:

Content: Annual survey to determine nuclear manpower demand for both experienced and new graduating students. Provides data by industry, education levels, functions to be performed (including R&D, design teaching), salary medians for current and previous year. Separate data for technician hiring. Supplemental survey covers ANS members who are new graduates hired for full time employment (courses, salaries, employment).

Coverage, Survey Method, Sources, Sample: Cooperating organizations (50 listed) in nuclear industry-mail questionnaire.

Reference Date: Yearly

Frequency: Annual

Forms and Reports: Nuclear Employment Outlook '75.

Evaluation Commentary: This report useful as indicator of demand/supply trends. Uncertain as to proportion of coverage of industry. Student membership questionnaire apparently low in coverage of new graduates.

NATIONAL SURVEY OF COMPENSATION PAID TO SCIENTISTS AND ENGINEERS ENGAGED IN RESEARCH AND DEVELOPMENT ACTIVITIES (ANNUAL SURVEY) ERDA-76/157

Agency: Battelle, Columbus Labs, Columbus, Ohio, for Industrial Relations Division, ERDA

Description:

Content: Annual survey, going back to late 1940's when it was conducted by Los Alamos Lab of the Atomic Energy Commission (AEC). Battelle did its 9th survey in 1976. Monthly salary data are given for supervisory and nonsupervisory scientists and engineers, by degree level, age, years since bachelor's degree, type of institutions (nonprofit research institutes, educational institutions, contract research centers, Federal establishments, industry), and occupation (working-as)-(8 kinds of engineers, physics, chemistry, atmospheric/earth/marine/space scientists, agricultural/biological scientists, economists, mathematicians/statisticians, and computer scientists). Also shows rates for technicians in the establishments, and percentage without degrees.

Coverage, Survey Method, Sources, Sample: All establishments employing scientists and engineers engaged in R&D universe of 7,617 establishments (1976 survey) stratified by type (see above), size, and size of standard metropolitan statistical areas in which located. Establishments with less than 40 scientists and engineers in R&D were omitted. Sample "randomly" selected, but only 304 of 802 establishments contacted responded (9 of 61 educational institutions, 221 of 595 industrial establishments, etc.) so responses could be biased. Data are based on report on individuals, some filled out by individuals, some by their firms from records.

Battelle sends an annual contract report to ERDA discussing technical limitations and plans for technical improvement.

Reference Date: 1976 latest

Frequency: Annual

Forms and Reports: Copies of the 2 forms used (employee and employer forms) and accompanying instructions are in back of 1976 report.

Evaluation Commentary - The low rate of response makes bias possible. Sampling errors are calculated, assuming random selection.

Data are displayed with means, medians, 10th, 25th, 75th and 90th percentiles, by age and years since first degree. The series may be valid as a measure of trend even if level is subject to bias.

Differential response rate by type of institution may also introduce bias.

NATIONAL SURVEY OF PROFESSIONAL, ADMINISTRATIVE, TECHNICAL, AND CLERICAL PAY (PATC)

Agency: Bureau of Labor Statistics, U.S. Department of Labor
Unit: Office of Wages and Industrial Relations

Description:

Content: Shows average salaries and annual changes, in private industries, of 20 occupations at 82 work levels; includes salary series for 8 levels each of Chemist and Engineer -- 2 entry and 6 worklevels -- plus 5 levels of Engineering Technician. Is used to equalize Federal pay levels to those of private industries, hence reflects levels (& trends) directly of private, and indirectly of Federal, Chemists and Engineers. Trend data are also imputed to allied or similar occupations. Imputations not shown in this publication, determined by "President's Pay Agent" -- Directors of (1) Office of Management and Budget and (2) Civil Service Commission.

Coverage, Survey Method, Sources, Sample: Relates to establishments over a given size in the 48 conterminous United States (variable, e.g. manufacturing-over 250 employees; services-over 100 employees). Stratified sample of 3,000 establishments by industry for each relevant occupation. Data obtained by Bureau of Labor Statistics field economists through personal interview with personnel officers of establishments sampled.

Reference Date: March

Frequency: Annual (17th as of 1976)

When Available: October

Forms and Reports: National Survey of Professional, Administrative, Technical, and Clerical Pay, March 1976; U.S. Department of Labor; Bureau of Labor Statistics, Bulletin 1931, Washington, D.C. 1976.

Evaluation Commentary: Sampling errors relatively low (under 4 percent for 70 of 82 work levels) and survey control and definition of job content and level are rigorous. Levels and trends shown for surveyed categories of chemists, engineers and technicians probably most authoritative available and probably can be imputed to related occupations (most criticism relates to imputation of private industry responsibility levels to those of Federal employees as well as inter-occupational imputations). Although used in personnel practice to compare agency or establishment pay rates for individual occupations with that of norm, adjustments in Federal pay scales have in practice been made for all occupations across the board with a single average percent pay increase. Data shown in median and quartile detail may not reflect deviations in pay trends for specific subspecialties and other variables, but they do and are intended to reflect pay responses by industry to imbalances in supply and demand. Expansion of survey to include smaller firms has been tested (only a few occupations show significant changes in trend shown by regular survey). Survey is costly, but it is a reliable vehicle for precise pay data. Use of this survey for other scientist and engineer occupations and R&D functions should be considered if substantial expansion in Federally supported energy R&D increases need for more precise pay comparability data.

OCCUPATIONAL EMPLOYMENT STATISTICS SURVEY

Agency: Bureau of Labor Statistics and cooperating State agencies
Unit: Division of Occupational Outlook--Office of Employment Structure and Trends

Description:

Content: Survey of employment by occupation, reporting by employing establishment. Covers altogether about 2000 occupations. For scientific technical personnel occupations the number engaged in R&D is collected, as well as total employed. Scientific technical personnel occupations include 8 classes of engineers, 5 of draftsmen and technicians, 4 of physical scientists, 2 of math scientists, 1 of life scientists, and 1 of social scientists, and 17 craft occupations. Each industry is sent a special questionnaire with a standard list of core occupations and a list of the occupations appropriate to that industry; the STP occupations are on the core list.

Coverage, Survey Method, Sources, Sample: At present 40 states participate, with a separate probability sample for each, stratified by size in each state; largest plants are included with certainty. Over 70% response rate, varying up to 95% in some states. Sample is drawn from universe of unemployment-insurance-covered plants. Exclusions: self-employed, Federal Government, agriculture, and education. Health, Education, and Welfare has jurisdiction over education, but won't survey. Civil Service Commission publishes Federal employment by occupation. (National Science Foundation collects employment of scientific technical personnel in colleges and universities.) To supplement the 40 states, Bureau of Labor Statistics collects balance of United States as a unit, on contract with National Science Foundation. Sample for each state designed to give 3-digit industry detail for state plus some Standard Metropolitan Statistical Areas (2-digit in some states). In 40 states total sample is some 150,000 establishments; in remainder of United States about 10,000.

Reference Date: April-June. Survey phased in 3-year cycle: 1976, trade and Federally regulated industries; 1977, manufacturing; 1978, all other industries.

Frequency: Annual

When Available: States have data by end of calendar year.

Classifications: Standard Industrial Classification for industries; a hybrid occupational classification, major groups same as Census, detailed occupations close to Dictionary of Occupational Titles.

Forms and Reports: Program is described in Bureau of Labor Statistics Handbook of Methods.

BLS 2 (Cont'd)

Evaluation Commentary: Some large states still missing from state-by-state program. Gaps: (1) no reason why the self-employed shouldn't be included (reported separately from employees, by occupation). We miss mostly self-employed engineers, etc.; (2) agriculture, education--not many scientific and technical personnel missed, except in higher education, covered by National Science Foundation survey.

Reasonably fast schedule: National and State data available by end of calendar year; blown-up total estimates due to National Science Foundation by April 15. Estimates for National Science Foundation at 2-digit level only. With 70+% response, probably adequate to assure unbiased estimates--but this should be reviewed industry by industry and by size classes.

Hybrid occupation classification may be close to the new standard occupational classification system for scientific and technical Personnel occupations.

Sampling errors to be calculated for every estimate, National and State. Quality control in state and national Bureau of Labor Statistics offices by clerical and professional review. Computer-mechanized quality control, using standard deviation of the occupational ratio for the industry from the current survey; outliers are rejected. Original collection is by mail in some states, personal visit in others; in the latter, some states actually collect the data and match the job definitions on the questionnaire to those in the plant. For the Bureau of Labor Statistics part of the survey, personal visits will be made to 500-1000 plants, but some of the visits will be to secure cooperation, and the data will not be collected personally by the Bureau of Labor Statistics representatives in all cases.

Limitations: Confidentiality may restrict what can be published by industry for States; occupational comparability with Census and Current Population Survey will not be complete (35% error found in the latter two).

LABOR TURNOVER RATES

Agency: Bureau of Labor Statistics, U.S. Department of Labor
Unit: Office of Manpower Structure and Trends

Description:

Content: Rates of accession (new hires, other accessions) and separation (quits, layoffs, other separations), monthly for manufacturing industries (data also for selected mining and communication industries). Data are published for all manufacturing, durable and nondurable goods industries, all 2-digit standard industrial classification industries, and selected 3- and 4-digit industries.

Coverage, Survey Method, Sources, Sample: Based on shuttle schedule reports from stratified sample of establishments. Data cover all employees and include total of personnel actions (hirings and separations) for the calendar month. Base for calculation of rates is the midmonth employment estimate normally reported in the Employment, Hours and Earnings Survey. Turnover data are also published for states and selected local areas.

Reference Date: Calendar month

Frequency: Monthly

When Available: Month following reference month in press release, 2 to 3 months following in other Bureau of Labor Statistics publications.

Classifications: Standard Industrial Classification System

Forms and Reports: Data are collected on Form DL 1219, and are reported in monthly press release, "Labor Turnover in Manufacturing." Data also reported monthly in Employment and Earnings and Monthly Labor Review (both published by BLS).

Evaluation Commentary: Error not calculated. Substantial revisions are sometimes made in preliminary data published. Represents by far the most comprehensive and largest sample survey of turnover in manufacturing. No occupational identification is made--data refer to "All Employees"--hence applicability to specific occupations is doubtful. Energy industries in manufacturing, and bituminous coal mining can, however, be identified. Utility of these data for assessing energy R&D manpower situation lies in providing a background of turnover patterns and trends for all employees (particularly in certain energy-related manufacturing industries) against which to compare other data on personnel patterns and trends for Department of Energy or other energy R&D manpower.

TABULATIONS OF OCCUPATIONAL AND LABOR FORCE STATUS CHANGES FROM 1965 TO 1970

Agency: Bureau of Labor Statistics, U.S. Department of Labor
Unit: Office of Occupational Structure and Trends

Description:

Content: Data are from the 1970 Census of Population, in which there was a question on labor force status, place of residence and occupation in 1965, which was asked of a 5-percent sample. General tablulations comparing 1965 and 1970 status and residence were published by the Bureau of the Census in Occupation and Residence in 1965, Subject Report No. PC(2)-7E, June 1973. Specific changes for individual occupations were tabulated by Bureau of Labor Statistics using 3 percent of the population (3 one-percent Public Use Samples). Data shown for each occupation include status in 1965 classified by status in 1970--not in labor force, dead, transferred to different occupation, or employed in same occupation. (Those dead in 1970, and, of course, not reporting to the Census, were estimated by applying to all persons reporting themselves to have been in an occupation in 1965, by age groups, "inverse survival rates" to estimate the additional number who were in those occupations in 1965 but who had died by 1970.) Data shown for each occupation (in separate tabulations available from Bureau of Labor Statistics) also include status in 1970 classified by status in 1965--not in labor force, employed in a different occupation, or employed in the same occupation. These data are tabulated by sex.

Coverage, Survey Method, Sources, Sample: The 3-percent sample is representative of the population enumerated in 1970. Sampling error is present especially for smaller occupations and when the data are classified by status and sex. The data can also be classified by age and other characteristics tabulated in the 1970 Census, but relative sampling error becomes so large as to make many of the figures unusable for analysis.

Reference Date: 1965 and 1970 (April)

Frequency: Has been done only for this period.

Forms and Reports: Data are presented in an article by Dixie Sommers and Alan Eck, "Occupational Mobility in the American Labor Force," Monthly Labor Review, January 1977, pp. 3-19. Additional tabulations are available on request to Bureau of Labor Statistics.

Evaluation Commentary: Principal deficiency is the inaccurate reporting of status in 1965, as well as failure to report occupation in that year. It is estimated that the statistics overstate transfers into 1970 occupations by about 14 percent, on the average, and overstate all other entrants to 1970 occupations by about 6 percent. Full discussion in Bureau of the Census report Accuracy of Reporting Work Status and Occupation Five Years Ago, Report E 15, No. 3, February 1970 (unpublished). There are also errors in reporting and coding 1970 occupation. Any error in the occupation reported for either 1965 or 1970 could affect the measurement of mobility substantially, since mobility is a characteristic of a minority of workers.

CURRENT EMPLOYMENT, HOURS AND EARNINGS STATISTICS

Agency: Bureau of Labor Statistics, U.S. Department of Labor
Unit: Office of Employment and Unemployment Analysis

Description:

Content: Monthly statistics on employment, average weekly hours, average weekly earnings and average hourly earnings for employees in nonagricultural establishments. Data published for over 400 individual industries at a national level. Employment of all workers and of production or nonsupervisory workers is reported for each industry. Employment by sex is published quarterly. Data for States and 220 metropolitan areas is published by the cooperating State agencies in somewhat less industrial detail.

Coverage, Survey Method, Sources, Sample: All nonagricultural establishments are covered. Excluded groups of workers are the self-employed, domestic workers, unpaid family workers, and those working in agriculture. Reporting sample is 158,000 establishments with 31 million employees. Mail questionnaire is returned monthly to State agency which compiles State and local estimates and sends individual establishment data to Bureau of Labor Statistics for compilation of national estimates. Monthly employment change is estimated by percent change shown by firms reporting in current and previous months; these changes are used to carry forward an estimate of total employment in each industry made annually from unemployment insurance tax reports and other sources.

Reference Date: Week including the 12th of each month

Frequency: Monthly

When Available: First week of following month

Classifications: Standard Industrial Classification

Forms and Reports: National data in full detail and State data by broad industry groups are reported monthly in BLS report Employment and Earnings. State and local data are published more fully by State agencies. Historical data (important because all figures are subject to revision up to 2¼ years after publication) are published in Employment and Earnings: United States (Bulletin 1312) and in Employment and Earnings: States and Areas (Bulletin 1370) which are reissued annually.

Evaluation Commentary: Current issues of Employment and Earnings have technical notes showing average errors in the estimates for industries of different size groups--e.g., average for industries of 100,000 employees is 2.7 percent. Hours reported are hours paid for, not hours worked (i.e., include vacation and holiday hours) and hourly earnings are estimated on this basis. Workers with more than one job who appear on more than one payroll are counted more than once; this duplication is estimated at about 3 percent in nonagricultural employment.

MINERAL FACTS AND PROBLEMS

Agency: U.S. Department of the Interior
Unit: Bureau of Mines

Description:

Content: An annual compilation (1975 edition was the 5th) of information on minerals and the mining industry. The 1975 edition (a Bicentennial volume) contains information on world and U.S. reserves and resources, U.S. and world mineral production capacities including estimates for 1980, locations and capacities of smelters for copper, lead, zinc, and aluminum, recycling, diagrams for major commodities, and projections of minerals in the U.S. economy to the year 2000. Separate chapters are available on practically all minerals including anthracite and bituminous coal, petroleum, natural gas and uranium.

Coverage, Survey Method, Sources, Sample: Data obtained through standard statistical series of the Bureau of Mines and other sources. The data base for the long-term forecasts is 1973.

Reference Date: Annual

Frequency: Annual

Classifications: Bureau of Mines

Forms and Reports: Mineral Facts and Problems, 1975 Edition, Bureau of Mines Bulletin 667. Data are collected through standard BOM surveys.

Evaluation Commentary: This is the standard reference work on mineral commodities in the U.S. and abroad.

ANNUAL SURVEY OF SCHOOL ENROLLMENT (CPS)

Agency: Census Bureau, U.S. Department of Commerce
Unit: Population Division

Description:

Content: Whether or not each person is enrolled in a school (separate data for colleges), classified by age, sex, color or ethnicity, family income level, marital status, type of area in which living (metropolitan or other), level and control of school (public/private), years of school completed, year of college in which enrolled, type of college (2-year and 4-year), and whether attending full-time.

Coverage, Survey Method, Sources, Sample: Survey is made every October by adding questions on enrollment to the regular monthly Current Population Survey of employment and unemployment. Sample is (as of 1977) about 56,000 households nationally and the school enrollment questions are asked about every member of the household over 3 years of age. Data on whether enrolled can be tabulated by any other characteristic collected in the survey that applies to the individual or to the whole family.

Reference Date: October

Frequency: Annual

When Available: Preliminary report about 8 months later, final report about 1 year.

Forms and Reports: Reports are designated series P-20.

Evaluation Commentary: Sample is adequate for demographic analysis of school and college attendance rates by demographic groups. Report is based on information from a responsible member of the household, not necessarily the student, so information on characteristics of schools or course of study (occasionally asked) may not be fully accurate. "School" as defined excludes "special" schools, defined as those not in the regular school system, such as trade schools or business colleges, but the report tabulates the numbers enrolled in such schools (over 1 million persons) by age, sex, color and whether they are high school graduates.

(1) CENSUS OF MANUFACTURES
(2) ANNUAL SURVEY OF MANUFACTURES

Agency: Census Bureau, U.S. Department of Commerce
Unit: Industry Division

Description:

Content: General data by industry (energy-related industries can be identified) on: all employees, production workers, manhours, payroll, cost of materials, value added, value of shipments, capital expenditures, inventories. Also includes special data on supplemental labor costs, and ad hoc data on energy such as "Fuels and Electric Energy Consumed" (1974). Data available by state. Related data are collected in Census of Mineral Industries.

Coverage, Survey Method, Sources, Sample: Complete census is conducted every five years; annual surveys represent sample survey extensions. Sample includes 70,000 manufacturing establishments of a universe of 300,000. Scope, coverage, survey methods are described in detail in regular survey reports.

Reference Date: Calendar year

Frequency: Annual (full census is quinquennial)

When Available: About 1½ years after reference year

Forms and Reports: Reported in chapter preprint bulletins and consolidated bulletins under survey title (Annual Survey of Manufactures, 1974, etc.) Survey forms are reproduced in most bulletins.

Evaluation Commentary: Standard errors are calculated and shown for most estimates. Sample design and coverage and survey techniques regarded as high quality. Identification of energy R&D or of occupations is not made in this survey and not considered feasible. Value of the data for energy manpower analysis is indirect, relating to composition and level of economic activity of energy industries, fuel consumption by fuel source for all industries, state and regional concentrations, labor costs and similar economic background data.

CURRENT POPULATION REPORTS - SERIES P-60
MONEY INCOME IN 1975 OF FAMILIES AND PERSONS IN THE U.S.

Agency: Census Bureau, U.S. Department of Commerce
Unit: Family and Individual Income Statistics Branch

Description:

Content: Annual income of families and individuals, by income class interval, according to a variety of personal, family and work characteristics, the most relevant being occupation and industry of longest job during the reference year. Occupations include broad categories ("professional, technical and kindred workers") with some further detail added in recent years ("engineers, technical") and consideration being given to identifying some additional detail such as "scientists and mathematicians."

Coverage, Survey Method, Sources, Sample: Uses Current Population Survey sample of the population. Approximately 50,000 households are interviewed, with the income queries asked each March.

Reference Date: 1975 (latest)

Frequency: Annual

When Available: About March of 2nd year after reference year

Classifications: Census Occupation and Standard Industrial Classification

Forms and Reports: Census Bureau P-60 Series Current Population Reports on Consumer Income - Money Income in (Year) of Families and Persons in the United States.

Evaluation Commentary: Although some additional occupational detail is being considered and provided on professional, technical and kindred workers to identify scientists and engineers, specific identification of scientist and engineer specialties, or of energy R&D affiliation, does not seem feasible given the sample size of the survey. Main use of these data is to depict income status (both level and trend) of scientists and engineers as a class compared to all other occupational categories. Such data would be suggestive of the socio-economic status of scientists and engineers and of changes that may be taking place in their relative position.

Most of the estimates show rigorously defined ranges of statistical error to guide interpretation of the data.

SURVEY OF GRADUATE ENROLLMENT

Agency: Council of Graduate Schools (CGS)/Graduate Record Examinations Board (GREB)

Description:

Content: For about 5 years the Council of Graduate Schools/Graduate Record Examinations Board have been conducting a two-phase survey of graduate enrollments. The first phase obtains from CGS members broad data on total and 1st time graduate enrollment by size of institution and control, and level of degree. Also collected are data on applicants for graduate study and on research assistants and fellows. The second phase in addition obtains data on enrollments by broad field (including the physical, social and biological sciences and engineering) by sex and by ethnic group.

Coverage, Survey Method, Sources, Sample: Mail questionnaires used for the two phases. The universe of 354 (CGS members) institutions grant either the masters or doctorate degrees. The first wave is mailed in early fall with response requested by November 1. The second phase is mailed the following spring with response by mid-October. Response to the 1976-77 survey was 91% for the first wave and 85% for the second. The CGS membership awards 99% of doctorates and 85% of masters granted.

Reference Date: Academic year

Frequency: Annual

When Available: See above

Classifications: CGS fields and levels (standard)

Forms and Reports: Fall and spring release of data - see releases of GREB.

Evaluation Commentary: A modest survey collecting few data; response is high and data are released quickly. Detail by field is poor as only broad areas are collected. All in all a good collection of information.

ANNUAL SURVEY OF JOB OFFERS TO COLLEGE GRADUATES

Agency: College Placement Council, Bethlehem, Pennsylvania

Description:

Content: Annual report on number of job offers made and salaries offered to graduates in each field. Occupations: the major engineering specialties, agricultural science, chemists, mathematicians, computer scientists, biological scientists, physicists and earth scientists, also business, accounting, humanities and social scientists. Degree levels: all 3 degree levels are tabulated separately, but with fewer fields at the higher levels. Salary data reported: average for each occupation at each degree level, and the 80% range. Types of Industries: 16 industries, government, non-profit. (Teaching jobs are not covered because other organizations collect this.)

Coverage, Survey Method, Sources, Sample: Reports from 160 schools. Job offers reported are actual offers made to individuals, not a general count of the number employers would like to hire. They contain duplication, since an individual may receive more than one firm offer, and a company may have to make several offers to hire one person. Last year the College Placement Council did a survey to find out how much duplication there was. It depended on the demand/supply situation in individual fields. Was as low as 1:1.5 in some occupations. This year it's more competitive.

Reference Date: Spring

Frequency: Annual

Forms and Reports: Annual report costs $35.

Evaluation Commentary: With the partial sample, unknown amounts of duplication and incomplete reporting even for the schools sending in reports (neither the students nor the companies report all offers) the data are no more than a straw in the wind. Trends in salaries offered may be more useful than numbers of offers. What's reflected is the large-employer campus recruiting, and therefore small firms' demand and the job-hunting that students do themselves off campus are not reflected. In the humanities and social sciences where on-campus recruiting is not prevalent, the data don't mean much.

CPC 2

RECRUITING ACTIVITY REPORTS
(a) WHAT EMPLOYERS PLAN TO HIRE (DECEMBER)
(b) WHAT EMPLOYERS ACTUALLY HIRED (JUNE)

Agency: College Placement Council, Bethlehem, Pa.

Description:

- Content: "December" report (a) number of persons employers expect to hire in the 4 major groups - engineering, science, math and other technical fields, business and other nontechnical fields. (Also a category of hires for which the discipline or major is not a consideration, as for example, insurance sales.) Tabulated by industry sector. Employers report on the form the comparable figure for last year, and all analysis is in terms of the year-to-year percentage change.

  "June" report (b) number actually hired, compared to number hired last year. Same classification of occupations and types of employers.

  Coverage, Survey Method, Sources, Sample: 700 employers report; Civil Service Commission gives good coverage of Federal government, but state and local governments are weak. Industries other than manufacturing, transportation and utilities are weak.

  Reference Date: December and June

  Frequency: Annual

Forms and Reports: Reports cost $5.

Evaluation Commentary: The sample is probably strong in some sectors, weak in others, and so what we have is difficult to evaluate. The collection of year-ago data on the same form assures an accurate comparison of the percentage change, but the reporters in December and June are usually not entirely the same. (A recent test of a matched group of reporters in December and June showed little difference from the comparison than was found in the unmatched totals.)

2

ENGINEER/SCIENTIST DEMAND INDEX

Agency: Deutsch, Shea and Evans, 49 East 53rd Street, New York, New York

Description:

Content: Consists of a three part index indicating the level of recruitment activities for engineers and scientists. One part is classified advertising from 15-20 newspapers in each of four geographical areas (Sunday classified ads for degreed persons); second part is display ads in all issues of newspapers; third is the number of ad pages in technical journals. The index has been issued monthly since 1961. Current base is average for 1961 = 100.

Coverage, Survey Method, Sources, Sample: See above. Part one is weighted for 50% of the overall index; second part is 25%; and third, 25%. Newspapers count ads in terms of agate lines for parts 1 and 2.

Reference Date: Each month

Frequency: Monthly

When Available: Following month

Forms and Reports: None--corresponding media furnish most data--staff oversee operation--a monthly release issued.

Evaluation Commentary: The index can be viewed as a confirming indicator of the fluctuations in the levels of recruitment activity. The collection organization (Deutsch, Shea and Evans) is a management consulting firm. There is no claim for the activity being a statistically valid sample. Recruitment advertising must be for degreed personnel and appear legitimate (no institutional ads per se are included). Though no details are provided by occupations, the overall index does provide a measure of the "level of demand".

PROFESSIONAL INCOME OF ENGINEERS

Agency: Engineering Manpower Commission (EMC)

Description:

Content: The 1976 survey was the twelfth in a series of collections made since 1963. Among the data collected are annual salaries of engineers by years of experience after degree, by supervisory and nonsupervisory positions, by level of degree (B.S., M.S. and Ph.D.), and by industry. The main survey covers employees in the major sectors of the economy with a special survey covering most engineering schools.

Coverage, Survey Method, Sources, Sample: The 1976 survey data were obtained between May and June of that year. Employers are requested to supply annual salaries of engineers in their employ. The total number of respondents was 906 in 1976 covering 163,000 engineers (about 15% of the total) of whom 531 were in private industry, 364 in education, and 71 in government. The Engineering Commission tries for a "representative coverage of industries," but this is not a statistically valid sample.

Reference Date: Annual

Frequency: Biennial

When Available: 6 months after collection

Classifications: EMC definitions and classifications.

Forms and Reports: Professional Income of Engineers, 1976, EMC. Questionnaire is included in report.

Evaluation Commentary: This survey collects very useful information on salaries paid to engineering graduates by employers in the several sectors of the economy. However, other than for almost complete coverage of engineering schools, the respondents do not represent a statistical sample of universe in any sector, About 15% of all engineers are covered.

SURVEY OF PLACEMENT OF ENGINEERING GRADUATES

Agency: Engineering Manpower Commission of the Engineers Joint Council

Description:

Content: Employment status of each year's engineering and 4-year engineering technology (associate degree) graduates, by field and level of degree. Graduates are classified as employed (those in new jobs and those returning to jobs previously held), entering full-time graduate study, entering military service, still considering offers of employment, those with no employment offers or other plans (seeking employment separated from not seeking employment), those with other plans (such as foreign students returning home), and those for whom no information was available.

Coverage, Survey Method, Sources, Sample: Survey covers about 172 engineering schools and 207 schools offering engineering technology (associate degrees) or bachelor of technology degrees. Information is obtained from an official of each school in the late Spring of each year. Schools accredited by the Engineers' Council for Professional Development and some not so accredited are included, and separate placement figures are shown for the graduates of each.

Reference Date: Spring of each year

Frequency: Annual

When Available: End of year

Forms and Reports: The latest report is Prospects of Engineering and Technology Graduates, 1976, New York, EMC, 1977. Questionnaire is reproduced at the back of the report.

Evaluation Commentary: Accurate information on the exact status of graduates is not always available to officials of schools, some of whom do a better job than others in keeping in touch with new graduates. "No information" is reported on from about 10 to over 20 percent of the graduates at various degree levels in 1976, and the information on the others is not always accurate. Nevertheless the trends in the labor market are picked up by the survey -- which showed the proportion of bachelors' degree graduates with no job offers or plans (and not entering graduate school or military service) rising from less than 1 percent in 1969 to 14 percent in 1976.

ERDA 1

REPORT OF CONTRACTOR HOURS AND EARNINGS (ERDA)

Agency: Energy Research and Development Administration (ERDA)
Unit: Division of Labor Relations

Description:

Content: Includes employment, payroll, and man hours worked (for non-professionals) by production and related; clerical and related; technicians; executive, administrative, professionals; scientists and engineers.

Coverage, Survey Method, Sources, Sample: Coverage includes Government-Owned, Contract-Operated (GOCO's) facilities (approximately 60). Complete coverage. Reports are filled with ERDA field offices which check them and forward to headquarters. Approximately 100,000 employed in GOCO's.

Reference Date: Pay periods include 12th of March and September

Frequency: Semi-annual

When Available: Available in headquarters by mid-month following

Classifications: Generally compatible with BLS-790, employment and payroll reporting.

Forms and Reports: Data collected on AEC-341--summarized in Division of Labor Relations--See Contractor Statistics.

Evaluation Commentary: The 60 GOCO's covered include about 100,000 employees, about half of which are scientific and technical. Semi-annual coverage provides periodic updates for nuclear energy supported by government. Insufficient detail on occupations, however, as well as type of activity, i.e., R&D, etc.

Related to Bureau of Labor Statistic annual survey of employment in nuclear energy industry, including private utilities, construction, design, R&D, etc. with about double GOCO coverage.

2

ERDA 2

REPORT OF CONTRACTOR EMPLOYMENT AND TURNOVER (AEC-252)

Agency: Energy Research and Development Administration (ERDA)
Unit: Division of Labor Relations

Description:

Content: Separate male/female, individual contractor, minorities employment by occupation category (i.e., professionals, technicians, etc.) at beginning of period; separations by type, accessions, and employment at end of period; promotions.

Coverage, Survey Method, Sources, Sample: Coverage includes all Government-Owned, Contractor-Operated (GOCO) establishments--approximately 60. Data collected by ERDA field offices, checked and forwarded to headquarters.

Reference Date: 6 months, calendar year

Frequency: Semi-annual

Forms and Reports: Data summarized by ERDA Labor Relations Division and distributed in Contractor Statistics, Industrial Relations.

Evaluation Commentary: Employment data for GOCO's by category--no detailed occupations--detail on minorities employment. Will need more occupational detail (electrical engineers, physicists, chemists, etc.) for RD&D uses.

NUCLEAR ENGINEERING ENROLLMENTS AND DEGREES, 1975

Agency: Energy Research and Development Administration (ERDA)
Unit: Office of University Programs/Manpower Assessment Office

Description:

Content: Fifth survey of all institutions offering degrees and options in nuclear engineering. Includes undergraduate and graduate enrollment by full-time and part-time status (also by year for undergraduates), degree granted by level, curriculum or option (nuclear, electrical, etc.), race, sex, and citizenship. Supplement covers postgraduate education and employment plans. Selected data from primary survey shown by school.

Coverage, Survey Method, Sources, Sample: Sixty-nine institutions covered in 1975, but the coverage varies by year as schools add or drop curriculums and options. Mail questionnaire is sent to schools. 1975 report shows data for all schools covered and control universe for reporting all five years. Survey is conducted by Oak Ridge Associated Universities for ERDA.

Reference Date: Academic year

Frequency: Annual

When Available: Year after survey (1975 report released July, 1976).

Classifications: ERDA energy curriculum options.

Forms and Reports: Questionnaire is included in report. Copies of previous survey reports available from ERDA.

Evaluation Commentary: Probably almost complete coverage of one selected area of energy education--nuclear engineering. Response appears to be good; however, response varies as schools add or delete option or curriculum. Names of reporting schools are published in report; therefore, schools or other interested parties can allow for exclusions and fill in for what is missing. Main limitation is lack of coverage of non-nuclear energy options.

RADIATION PROTECTION ENROLLMENT AND DEGREE SURVEY

Agency: Energy Research and Development Administration (ERDA)
Unit: Office of University Programs/Manpower Assessment Office

Description:

Content: Includes full or part-time enrollment by level (undergraduate, master, doctorate) in Fall 1975, and degrees granted (bachelor, master, doctorate) July 1974-June 1975 by program option. Minorities and women separately identified. Supplement provides information on employment of graduates by type and degree level.

Coverage, Survey Method, Sources, Sample: 1975 survey covers 58 institutions offering education programs in fields of radiation protection such as health physics, radiation health and safety, radiological health, and similar. Conducted by Oak Ridge Associated Universities for ERDA. 1975 survey concluded in October 1975--returns due 11/10/75.

Reference Date: Fall 1975 for enrollments; academic year 1974-5 for degrees.

Frequency: Annual

When Available: 1975 report dated July 1976.

Classifications: Non-standard

Forms and Reports: Schedule included on page 51 f. of Radiation Protection Enrollments and Degrees, 1975.

Evaluation Commentary: Coverage appears complete although not all items reported, e.g., minority enrollments.

1975 survey is 5th annual survey.

Not clear how many graduates become employed in RD&D activities in energy, but data provided on placement of graduates in government, academic institutions, GOCO's, and industry.

SURVEY OF OCCUPATIONAL EMPLOYMENT IN NUCLEAR OR NUCLEAR RELATED ENERGY ACTIVITIES

Agency: Bureau of Labor Statistics (BLS) for ERDA
Unit: Division of Manpower and Occupational Outlook

Description:

Content: 1975 survey was 14th conducted since 1960. Employment--total and in R&D--by occupation in these activities; sources of funds (Federal Government, own organization funds, other funds); and current difficulties in hiring personnel; employment by segment of nuclear activities. Occupations: 7 types of engineers, mathematicians, 4 types of physical scientists, 4 types of life scientists, 8 types of technicians, welders with nuclear certification, other. Segments: 21 segments of nuclear or nuclear-related activities, such as uranium milling, chemical reprocessing of irradiated fuel, transportation of nuclear materials, reactor research, etc.

Coverage, Survey Method, Sources, Sample: Coverage is all known private industrial establishments authorized to deal with nuclear materials, and all Government-Owned, Contractor-Operated (GOCO) related to ERDA. Mailing list furnished by ERDA. About 60 GOCO plants and 1,060 privately owned establishments in 1975 survey. Mail survey. Total employment: 108,000 in nuclear activities (200,000 total company employment).

Reference Date: Mid-year

Frequency: Biennial (formerly annual)

When Available: Usually a year after survey

Forms and Reports: Employment in Nuclear Energy Activities 1975, ERDA. The BLS also issued a release on results of the survey.

Evaluation Commentary: Coverage of plants in survey scope is virtually complete. The survey has been conducted long enough to achieve an understanding of terms on the part of respondents, and the data are reasonably accurate.

AN ANALYSIS OF NUCLEAR RELATED TECHNICIAN MANPOWER IN WESTERN STATES (ERDA-78)

Agency: Oak Ridge Associated Universities For ERDA
Unit: Manpower Development Division

Description:

Content: Report of a survey of nuclear related technician employment in the Western States covered by the Western Interstate Nuclear Board.

Survey covers both current employment (16,800 in January '75) and projected employment (22,300 by late '77).

Training program and graduates projected for similar period. Includes types of technicians and types of training programs by states and type of training or employment organization.

Coverage, Survey Method, Sources, Sample: Some 2600 organizations--employment or training--surveyed with 79 percent response, estimated to account for 95 percent of employment. Sample of non-respondents to mail questionnaire followed up for error estimates.

Reference Date: January 1, 1975

Frequency: Single time

When Available: On file

Classifications: Technical classifications developed for survey

Forms and Reports: Questionnaire schedules included in report ERDA-78 for both employing organizations and training.

Evaluation Commentary: Report appears to be a comprehensive examination of nuclear related technicians. Shortages anticipated for production and reactor operators and for test and measurement technicians; probably surplus of medical and health-related.

Tries to allow for attrition and growth in employment.

Usual difficulties with respect to losses to occupation and training attrition. Appears to be a workmanlike job.

Can expect differences in interpretation by employers of different types of technicians.

ERDA 7

INDUSTRIAL TRAINING IN NUCLEAR MANPOWER

Agency: Energy Research and Development Administration (ERDA)
Unit: Office of University Programs

Description:

Content: Using a listing of industrial establishments published by the American Nuclear Society (ANS), ERDA compiled an inventory of education, training and work experience programs for nuclear power plant and facility personnel supported or conducted by industrial firms. Information collected includes separate firm-by-firm listings describing the programs--the length and type (radiation protection, computers, instrumentation, reactor operation, etc.).

Coverage, Survey Method, Sources, Sample: As indicated, the original list of proposed respondents was taken from those firms indicating a "training" program in the American Nuclear Society 1976 and 1977 Buyers Guide. The response was simply that received and no indication of coverage can be made. Similar training opportunities are found in trade unions, Federal agencies, and professional societies.

Reference Date: Spring 1977

Frequency: Single time

When Available: 6 months after survey

Classifications: As found in survey

Forms and Reports: Industrial Training for Nuclear Power Survey. Methodology also described in report.

Evaluation Commentary: No evaluation can be made with respect to coverage since response was requested only from a special listing. And lack of response doesn't indicate lack of such training. The survey did provide useful information on nuclear training--but of course did not cover other energy programs.

ENERGY-RELATED TECHNOLOGY PROGRAMS IN COMMUNITY AND JUNIOR COLLEGES

Agency: Energy Research and Development Administration (ERDA)

Description:

Content: In 1975, ERDA supported a survey conducted by Oak Ridge Associated Universities (ORAU) with the cooperation of the American Association of Community and Junior Colleges (AACJC). Information obtained included the number of existing and planned energy-related programs (curriculum) and the type of involvement or cooperation between schools and industry. The programs are delineated into several energy categories (petroleum, coal mining, geothermal, etc.), type of school (public, private), location of school.

Coverage, Survey Method, Sources, Sample: The universe for the survey was AACJC mailing lists--members (891 schools) and nonmembers (333) of the organization. All schools were solicited and returns were received from 612 member and 162 nonmember schools. Follow-ups were conducted to determine bias in the response. Altogether, some 76 schools indicated existing energy-related programs and 153 indicated ones being planned. The follow-up indicated a likelihood of less frequent reporting of these programs among original nonrespondents.

Reference Date: End of Calendar 1975

Frequency: Single time

When Available: 6 months after survey

Classifications: As found in survey

Forms and Reports: Energy-Related Technology Programs in Community and Junior Colleges, An Analysis of Existing and Planned Programs. Questionnaire and methodology included in report.

Evaluation Commentary: This was a single-time survey which indicated a substantive trend toward the introduction of energy programs in these institutions. The survey should be conducted again in the near future.

COMPARISON OF COMPENSATION PAID SCIENTISTS AND ENGINEERS IN RESEARCH AND DEVELOPMENT--1976 DATA

Agency: Energy Research and Development Administration (ERDA)
Unit: Division of Labor Relations

Description:

Content: Represents special tabulations and analyses comparing compensation paid scientists and engineers in 18 ERDA laboratories with compensation paid scientists and engineers in other facilities represented in the Battelle National Survey of Compensation (See Data Source BATL 1). Data and comparisons are shown by type of establishment, education level, management level, age, degree level and years since degree. Analytical approach is essentially "age-wage," differentiating salaries according to chronological age maturity or years since receipt of degree.

Coverage, Survey Method, Sources, Sample: Survey methods and content essentially the same as BATL 1. Seven of the eighteen ERDA laboratories are included in the BATL 1 sample. This survey compares reports from all eighteen laboratories, separately aggregated and analyzed, with the totals and various categories of comparable "outside" universes shown in BATL 1.

Reference Date: 1976

Frequency: Annual

When Available: About February of year following reference year.

Forms and Reports: Annual reports available from ERDA (now Department of Energy) or National Technical Information Service.

Evaluation Commentary: This survey, along with that of the Battelle National Survey of Compensation, employs one of the most pragmatic approaches towards identifying the components on which compensation differences are based. These components involve primarily education, supervisory responsibility and age, and they appear to provide accurate standards for analytically realistic measurement and comparison of compensations for scientists and engineers. Response rate of ERDA laboratories portion of the survey seems to be perfect (as might be expected from the nature of the control and financial support), and the data may be considered highly accurate and representative for its universe. Unfortunately, the larger universe survey (BATL 1) experiences a low response rate, so that their survey results (which form one base of the comparison process) is statistically flawed even though conceptually sound.

EMPLOYMENT SERVICE APPLICANTS FILE

Agency: Department of Labor
Unit: Employment and Training Administration, U.S. Employment Service

Description:

Content: Applicants in State Employment Service offices who have not yet found jobs, tabulated by occupation (several hundred detailed occupations, by Dictionary of Occupational Titles Classifications)- for the United States, all States and 85 large metropolitan areas.

Coverage, Survey Method, Sources, Sample: All who are reported by State Employment Service Agencies as having filed job applications and whose names have not been deleted from the applicant files because they are known to have taken jobs.

Computerized file, ESARS (Employment Service Automated Reporting System), is tabulated quarterly.

Frequency: Quarterly

Forms and Reports: No publication, but quarterly tabulations are available on microfiche. Table 96 is the tabulation of the applicant file by occupation.

Evaluation Commentary: Applicants include people with jobs who want better jobs (underemployed?) as well as those unemployed.

Scientific and technical personnel typically do not use the public employment service to seek jobs, but where jobs are hard to get more applicants will show up; also, when someone receives unemployment insurance benefits, he is required to seek work through the public employment service. A rise in the number of scientist and engineer applicants is therefore a sign of deteriorating labor market, even though the total of applicants is not a measure of the number of scientists and engineers seeking jobs.

PROJECTING EMPLOYMENT REQUIREMENTS FOR ENERGY DEVELOPMENT AND EXPANSION IN FEDERAL REGION VIII

Agency: U.S. Department of Labor
Unit: Employment and Training Administration Region VIII (Denver)

Description:

Content: Based on Bureau of Mines and USDL manning tables and BOM "Projects to Expand Fuel Sources in Western States" to obtain manpower requirements for implementing these projects. Principal energy areas: coal mining, power plants, coal conversion facilities. Shows projected requirements by state in Region VIII (Colorado, Montana, North Dakota, Utah, Wyoming); by detailed occupation (specific jobs, e.g., front end loader operation). Includes construction of facilities and operation phases (except mining which does not include construction requirements). (No R&D or scientist manpower data.)

Coverage, Survey Method, Sources, Sample: Energy development projects reported to or known to BOM were applied to manning tables for the production capacity shown. Shows only direct employment requirements and does not attempt to net out labor force attritions due to retirement, death, separation.

Reference Date: 1976-1985

Frequency: One time

When Available: October 1976

Classifications: Dictionary of Occupational Titles, Standard Industrial Classifications.

Forms and Reports: Projections based on BOM Circular 8719 (Projects to Expand Fuel Sources in Western States) and USDL/BOM manning tables. See related speech by Robert J. Brown (then Regional Administrator ETA Region VIII, now Undersecretary of USDL) 10/14/76 Energy Employment: The Critical Dependency in the United States Economy to National Commission for Manpower Policy, San Francisco, California.

Evaluation Commentary: Based on fairly accurate manning tables developed by on-site surveys, less accurate reports by companies on planned energy projection projects, is subject to usual weaknesses of projections--in this case whether planned projects will be realized and whether technology will change. Also does not show indirect employment generated or show net employment additions required (after labor force attrition). Also limited to one region.

Nevertheless gives quantitative parameters of employment requirements to short term (to 1985) prospective expansion plans by specific (job title) occupations and demonstrates that employment needs can be estimated with fair degree of specificity for prospective energy expansion projects. No R&D occupations are involved in these projections, but highly skilled craftsmen occupations are included. Valuable mainly as a model for forecasting energy manpower requirements.

27

EMPLOYMENT SERVICE JOB OPENINGS: (1) JOB BANK OPENINGS SUMMARY (JBOS) (2) OCCUPATIONS IN DEMAND (OID) REPORT (3) JOB BANK FREQUENTLY LISTED OPENINGS (JOB-FLO) REPORT

Agency: U.S. Employment Service, U.S. Department of Labor
Unit: Job Search Information Unit

Description:

Content: JBOS represents national summary listing, by job bank region, of all retrievable job orders in the Public Employment Service for the reference month. Produced only in microfiche and has limited availability. OID is a selected summary of about 140 occupations either heavily in demand in one or more areas, or with substantial aggregate demand in five or more areas. Appears as an 8-page newspaper monthly. Includes certain "Frequently Listed Occupations" (FLO) according to multiple criteria of employment office size and volume of job order flow. Shows FLO openings during and at end of month. JOB-FLO reports monthly on selected characteristics of FLO according to industry generating orders, quantity, and experience and educational requirements of employees. Issued as computer print-out bulletin.

Coverage, Survey Method, Sources, Sample: Data are based on job order tapes of openings registered in job banks. JBOS includes all orders retrievable at national office; old reports on occupations heavily in demand,; JOB-FLO also focuses on high volume occupations regularly reported by about 125 large local offices, with analytical material. Selection criteria are described in information guides available with the reports.

Reference Date: Calendar month

Frequency: Monthly

When Available: About month later

Classifications: Dictionary of Occupational Titles (DOT) and aggregates thereof. Industries according to Standard Industrial Classification (SIC)

Forms and Reports: As described above.

Evaluation Commentary: Data represent only those job orders registered with the USES, which traditionally has been only a minor intermediary in the job market for scientists and engineers. Past experience with operational reporting difficulties, delays in transmission, and failures to "clear" the files of job orders no longer in force can be expected to blur the interpretation of the data as an accurate reflection of demand. However, if taken with other data, these openings data may provide confirmation, or initial indicators subject to confirmation, of developments in demand for specific categories of scientists and engineers. Additional analytical material is available, on limited basis at national office of USES, in "Analytical Table Series," which presents time series analysis by occupational category, wages, industries and areas.

APPRENTICESHIP STATISTICS

Agency: Department of Labor
Unit: Employment and Training Administration

Description:

Content: Statistics on apprentices in apprenticeship programs registered with the Bureau of Apprenticeship and Training or with State Apprenticeship Councils. Number in training at beginning of year, new registrations and reinstatements, occupations, cancellations, and number in training at end of year. Data available by occupation in which the worker is apprenticed (53 occupations plus miscellaneous). Data on the characteristics of apprentices, by occupation and industry, are available: race or ethnic group, sex, and veteran status.

Coverage, Survey Method, Sources, Sample: All registered programs, as defined above, are covered. Reports are from local program coordination.

Reference Date: End of calendar year

Frequency: Annual

Forms and Reports: Data regularly reported in the Statistics section of the annual Employment and Training Report of the President.

Evaluation Commentary: The non-registered programs, excluded from the data, are believed to train a large number of apprentices--sometimes said to be as many as those in registered programs, but there are no hard data on the number. Informal training also goes on for many of the trades, and many apprentices can get journeyman jobs before completing the program. The completions of registered programs do not, therefore, fully measure the total number of persons who enter the trades.

ANNUAL REPORTS OF INTERSTATE CARRIERS (PETROLEUM PIPELINES)

Agency: Interstate Commerce Commission
Unit: Accounting Division

Description:

Content: Annual reports of regulated companies usually include schedules, by individual carriers, on employment and compensation in addition to financial and operating information. The schedule on employment by regulated interstate oil pipelines calls for the average number and annual compensation of "professional and subprofessional employees." Some variation by type of company.

Coverage, Survey Method, Sources, Sample: All regulated companies are required to report.

Reference Date: Calendar year

Frequency: Annual

Classifications: Ad hoc occupational classification; 22 categories include such detail as "carpenters" and "telegraph operators" with broader categories such as "professional and subprofessional employees."

Forms and Reports: Information apparently not published, but available for public inspection of individual reports in Room 6114, ICC Building, 12th Street and Constitution Avenue, N.W., Washington, D.C.

Evaluation Commentary: Not sufficient occupational detail to provide more than general background information, i.e., "professional and subprofessional employees (engineers, chemists, etc.)" as detailed as pipeline report goes.

Employment represents the "average" for year with "total compensation for the year."

Data have limited utility as presently structured but undoubtedly will be consolidated into a uniform Department of Energy reporting system with more useful occupational detail.

BENEFICIARIES OF OCCUPATIONAL PREFERENCE AND OTHER IMMIGRANTS ADMITTED, BY OCCUPATION

Agency: U.S. Department of Justice
Unit: Immigration and Naturalization Service

Description:

Content: Occupations of all immigrants by category of admission (critical shortage occupations,* and all others, mainly relatives of U.S. Nationals**). FY 1976 report lists admissions by 11 categories of engineers, 8 life and physical scientists, 6 social scientists, 25 teachers, 9 engineering and science technicians, etc. Temporary students, who may become long-term, are generally classified as "nonimmigrants."

* 2nd largest for scientists and engineers
** Largest category by far for scientists and engineers

Coverage, Survey Method, Sources, Sample: Occupations based on entries supplied by immigrants (sometimes consular officials) on application for entry visa and applications for certification for immigrant entry because of critical occupational shortage.

Reference Date: Year ending June 30

Frequency: Annual--Data reported in Annual Report of the Commissioner of Immigration and Naturalization.

When Available: About 3 months after end of reference year

Classifications: Census occupation (roughly)

Forms and Reports: Application for immigration visas and for certification (by U.S. Department of Labor) of critical labor shortages (confidential records not usually available).

Evaluation Commentary: Uniform standards are not applied to occupational designations by immigrants. Also, occupation given is that before entry into U.S.A., and may not reflect actual occupation after immigration. Follow-up survey and analysis of records by David North for U.S. Department of Labor (MA) shows substantial occupational dispersion after entry, with tendency for mobility upward in occupational social and economic status (SES) for those at lower end, and mobility downward for those declaring themselves at upper end of occupational SES.

There is need for regular follow-up on occupational status (need for and feasibility of which demonstrated in D. North's study), better initial standardization of occupational designations, better coding, tabulating and publishing by Immigration and Naturalization Service, and some indication by analysis of discrepancies introduced by interventionary actions in the immigration process (e.g., FY 1976 certification of H-2 temporary workers--supposedly laborers--shows 328 engineers and 23 scientists admitted). Nevertheless, these are best indications of magnitude of foreign supply to U.S. of Scientific, Technical and Engineering Manpower.

See also, National Science Foundation, NSF Scientists and Engineers from Abroad: Trends of Past Decade, 1966-75, 77-305.

COAL MANPOWER PROJECTIONS, 1980

Agency: Kramer Associates, Inc.

Description:

Content: Projects manpower requirements for bituminous and lignite coal mining: aggregate manpower by type of mine (underground, strip, auger), by year 1974-80, using projections and other data (shown in detail) from other sources on type of production, output, age composition of work force, productivity (extensive detail and discussion), retirements and other attrition. Also: projection of employment by skill grade and illustrative skilled occupations. (But no R&D or scientist manpower coverage.)

Coverage, Survey Method, Souces, Sample: "Performed under contract with U.S. Department of Labor, Manpower Administration. Estimates manpower requirements on basis of projections of output made by National Petroleum Council (in U.S. Energy Outlook, 1971-85, published 1971-72). Using also: aggregate employment and productivity data, illustrative occupational composition in West Virginia, United Mine Workers data on age composition and attrition of labor force.

Reference Date: 1970-73 actual data; 1974-80 projections

Frequency: Single time

When Available: September 1973

Forms and Reports: None--calculations made on basis of other published data and judgmental analyses. Assumptions stated and judgmental factors given.

Evaluation Commentary: Report notes handicaps in making estimates of both aggregate and occupational manpower requirement projections owing to limitations of available data (quality, detail, existence). Relied heavily on West Virginia occupational employment detail to impute pattern to entire industry, and to secure comparability with other published occupational data such as union contract job titles. Also notes deficiency of detailed productivity data and its limiting effect on validity of these projections. Nevertheless a good broad cut at establishing order of magnitude of net additional manpower requirements in bituminous coal industry.

Primary improvements needed: more, and more comparable, occupational data and some breakdown of productivity measures now made by United States Department of Labor.

EARNED DEGREES CONFERRED--HIGHER EDUCATION GENERAL INFORMATION SURVEY (HEGIS)

Agency: Health, Education and Welfare
Unit: National Center for Education Statistics (NCES)

Description:

Content: Reports annual baccalaureate and higher degrees conferred by United States institutions of higher education. Includes level of degree (bachelor's, master's, doctor's, first professional); discipline speciality in which degree granted, type of institution (public/private, university or other), sex of recipient for each degree.

Data available also for individual institutions.

Coverage, Survey Method, Sources, Sample: Covers substantially 100 percent of approximately 1,800 institutions identified in Education Directory as offering bachelor's or higher degrees. Survey instrument is mail questionnaire to presidents of institutions or to State coordinators. Covers academic years July-June.

Reference Date: School years, July 1-June 30

Frequency: Annual

When Available: Nominally by January of following year. Data expected to be available on tapes by January of year following school year reported. However, 1975-76 tapes not available in June 1977, and last published report now available is for school year 1974-75. Availability date varies widely depending upon receipt of survey forms, editing, contractor processing, Government Printing Office printing schedules, etc.

Forms and Reports: Forms OE 2300-2.1 Degrees and Other Formal Awards Conferred: reproduced on p. 25f Earned Degrees Conferred 1974-75.

Individual institution data separately published in limited supply available.

Evaluation Commentary: Only source of comprehensive data on degrees granted by level and by discipline. Coverage of institutions substantially complete, but extent of possible error in reporting field of degree unknown. Machine edit for consistency with previous year report and mathematical accuracy supplemented with visual inspection and follow-up with institutions in questionable cases. Some differences found with National Research Council doctorate survey.

Classification of field of degree comparable back to 1970-71; can be converted to 1965-66.

Useful as indicator of potential supply for technical manpower programs, such as energy. Usefulness would be greatly enhanced by supplementary or follow-up surveys of education and degree backgrounds of the presently employed in energy activities.

STUDENTS ENROLLED FOR ADVANCED DEGREES--HIGHER EDUCATION GENERAL INFORMATION SURVEY (HEGIS)

Agency: Health, Education and Welfare
Unit: National Center for Education Statistics (NCES)

Description:

Content: Reports annually on students enrolled for advanced degrees (master's or higher and first professional) in U.S. higher education institutions. Includes sex, attendance status (full or part-time), whether less than or more than 1 year of graduate study complete and discipline speciality of major field of study.

Information also available on enrollments by discipline and individual institution.

Coverage, Survey Method, Sources, Sample: Questionnaire sent to all institutions--universities and 4 year reporting units--identified in Education Directory. Returns from 1,050 institution units cover all known to enroll students for advanced degrees in Fall 1974. Coverage complete. Mail questionnaires completed by institutions or State coordinators.

Reference Date: Fall term

Frequency: Annual

When Available: Nominally by June of following year, but in June 1977 the 1974 report last available. Tapes earlier.

Classifications: "Taxonomy of Intructional Programs in Higher Education" for major fields of study.

Forms and Reports: Form OE 2300-2.5 Students Enrolled for Advanced Degrees reproduced on p. 53f of Students Enrolled for Advanced Degrees Fall 1974, National Center for Education Statistics 76-112.

Evaluation Commentary: Only source of comprehensive information on students enrolled for graduate study in all fields. The 965,000 enrolled for master's and doctor's and the 223,000 enrolled for first professional degrees exclude graduate level students enrolled in courses which do not terminate in advanced degrees, and post-doctorates.

Comparability good back to 1971 when discipline specialities first classified according to "Taxonomy of Instructional Programs in Higher Education."

Useful to estimate higher education trends for disciplines of interest to energy manpower. Needs supplemental information on education and training of manpower now engaged in energy work.

ASSOCIATE DEGREES AND OTHER FORMAL AWARDS BELOW THE BACCALAUREATE--HIGHER EDUCATION GENERAL INFORMATION SURVEY (HEGIS)

Agency: Health, Education and Welfare
Unit: National Center for Education Statistics (NCES)

Description:

Content: Reports annual awards of associate degrees and other formal awards based on less than 4 years of college-level work by [illegible] institutions of higher education. Primarily emphasizes completions of organized occupational curriculums in variety of technologies normally offered in 2-year collegiate programs to prepare students for immediate employment. Includes associate degrees (at least 2 years and less than 4 years beyond secondary) and other awards (requiring 1 year beyond secondary); type of control (public/private); type of institution (university, other 4 year, 2 year); curriculum (arts and science or general, science or engineering related occupational); discipline specialties; sex of recipients.

Data also available for individual institutions and States.

Coverage, Survey Method, Sources, Sample: Coverage base--"institutional units" identified in Education Directory as universe of those offering programs requiring at least 2 years of college work but less than 4 years.

Survey instrument mail questionnaire to presidents of institutions or State coordinators. Response substantially complete (3 nonrespondents in 1974-75).

Reference Date: School years, July 1-June 30

Frequency: Annual

When Available: Nominally January of following year. Data frequently delayed--published report for 1974-5 became available in June 1977.

Classifications; Discipline specialties--"Taxonomy of Instructional Programs in Higher Education"

Forms and Reports: Form OE 2300-2.1, Part C, Degrees and Awards Based on Less Than 4 Years Work Beyond High School reproduced on p. 39f of Associate Degrees and Other Formal Awards Below the Baccalaureate 1974-75 (NCES 77-327).

Evaluation Commentary: Source of comprehensive data on an admittedly murky area of post-secondary education leading to entry into technical, semi-professional, and in some cases professional occupations. Does not include technical training programs in secondary schools, employer on-the-job and apprentice training, or armed forces, all of which are important training mechanisms.

Comparability good back to 1973-4, and fair to 1970-1. However, categories have been added to specialties since 1971, and other revisions made.

Useful as indicator of potential supply for technical manpower programs with entry at semi-professional and technical occupational level. Needs supplementary information on education and training of new entrants presently employed in energy R&D programs.

UPPER DIVISION ENROLLMENT BY DEGREE FIELD
HIGHER EDUCATION GENERAL INFORMATION SURVEY

Agency: Health, Education and Welfare
Unit: National Center for Education Statistics (NCES)

Description:

Content: This is a new section added to the Higher Education General Information Survey (HEGIS) requesting information on numbers of upper division students by major field of study. It was combined with the regular survey of students enrolled for advanced degrees. Information is provided on enrollments by field, sex, full or part-time study and by institution and geographic location. In a separate section, information was requested also on students enrolled for first professional degrees.

Coverage, Survey Method, Sources, Sample: All institutions awarding at least a bachelor degree which are included in the Education Directory of Higher Education were contacted. Data were furnished by 1,658 institutional units (separately organized campus or branch of larger universities or state systems). Upper division enrollment is defined as juniors and seniors enrolled for 4- or 5-year baccalaureate degrees. A response rate of 100% of the institutions was obtained.

Reference Date: Fall of year

Frequency: Periodic

When Available: About one year following referenc ate.

Classifications: Taxonomy of fields of study of the National Center for Education Statistics.

Forms and Reports: Questionnaire with instructions contained in reports. A report Upper Division Enrollment, by Field, was issued in mid-1977.

Evaluation Commentary: This is the first collection of such data since 1967. At present the NCES is not certain how often the upper division or graduate enrollment surveys will be conducted. It appears that both surveys enjoy very high response rates ~~and have~~ no special trouble with definitions, etc. The problem for the NCES is one of priorities of surveys.

NCES 5

SURVEY OF RECENT COLLEGE GRADUATES

Agency: Westat, Inc. for National Center for Education Statistics (NCES)

Description:

Content: Concentrating on obtaining information on possible additions to teaching supply. The survey obtained information from a sample of college graduates at the bachelor's and master's degree level of 1974-75 on: support during undergraduate work (loans, scholarships, etc.), completion of requirements for teaching certificate and fields of same, continued student status, salary, teaching activities by field, relation of major to job, language competency, major field of study, and selected personal characteristics.

Coverage, Survey Method, Sources, Sample: Westat, Inc., under contract to NCES, conducted this survey of 1974-75 graduates in mid-1976. The sample design consisted of 4000 bachelor's and 1600 master's degree recipients selected on a two-stage basis from a sample of universities and colleges (actually about 5800 from 200 schools). Some 4,350 usable replies were received. Sample was weighted up to the counts obtained in the Higher Education General Information Survey (HEGIS) 1974-75. The sample was weighted to include over-representation for education majors. Additional data on methodologies used in the survey are found in the report listed below.

Reference Data: Spring 1976

Frequency: Single time

When Available: One year after survey

Classifications: NCES Taxonomies

Forms and Reports: Two reports have been prepared but are not yet released: Methodological Report, Survey of Recent College Graduates, 1974-75 and Survey of 1974-75 College Graduates. The questionnaire will be contained in the former report.

Evaluation Commentary: Though felt to be a successful survey in terms of meeting the broad purposes of the National Center, it is weak with respect to providing data on science and engineering graduates. This results from the intended bias toward education majors and thus the number of cases was not large enough to provide detail on most science and engineering disciplines. NCES, in November 1977, signed a contract with the National Opinion Research Center (University of Chicago) to conduct a new similar survey for 1977 graduates.

SURVEY OF EARNED DOCTORATES

Agency: National Research Council
Unit: Commission on Human Resources

Description:

Content: Name, sex, race, citizenship, high school and college education (year and location of institution, field and title of degrees), title of thesis and thesis advisor, source of financial support in graduate school, academic status in year prior to award, immediate post graduation plans (fellowship, employment, military, and broad type of employer), name of employing organization. Occasionally one or two additional questions asked, e.g., education of father and mother.

Coverage, Survey Method, Sources, Sample: Questionnaire distributed to each candidate for doctoral degree in all U.S. schools by Graduate Deans or similar official. Questionnaire returned to NRC at award of degree. Returns for many years have been at over 99% rate. Some follow-ups are made. Covers all fields and institutions awarding earned doctorates. Survey has been carried out on this basis since 1957. However, NRC has computerized file of all earned doctorates since [illegible]

Reference Date: Academic year

Frequency: Annual

When Available: About 9 months after end of year.

Classifications: National Research Council/National Science Foundation fields of science and engineering.

Forms and Reports: Annual report Doctorate Recipients from United States Universities includes questionnaire. Occasionally summaries of data for several years produced.

Evaluation Commentary: This is practically complete coverage of earned doctorates from a U.S. university. Furthermore, a computerized file of all data for all years is maintained by NRC. Individual completing questionnaire states his field of study. Therefore data not strictly comparable with National Center for Education Statistics data on earned doctorates. No information on energy-related activities.

SURVEY OF DOCTORAL SCIENTISTS AND ENGINEERS

Agency: National Research Council (NRC)
Unit: Commission on Human Resources

Description:

Content: Covers demographic, educational, and professional characteristics of doctoral scientists and engineers--age, sex, place of birth, race, citizenship, education (each degree by field, date, and institution), labor force status, employment by field, work activity, employer (broad industry group), academic status, location, area of national interest (energy, etc.), and support by Federal agency. Survey supported primarily by National Science Foundation.

Coverage, Survey Method, Source, Sample: Mail questionnaire survey to sample of individual doctorates; the basic sample selected for first survey in 1973 is contacted every two years, with addition of two new classes of awardees. Sample selected from universe of doctorate awards (since 1920) and National Science Foundation Register. Sample about 1 in 5, but stratified by field, year of degree, sex, size of doctorate institution. Response rate in 1975 about 70%. Response has been in general similar across stratification--errors are shown in 1975 report. Third survey for 1977 underway.

Reference Date: February-March

Frequency: Biennial

When Available: A year after survey

Classifications: National Research Council/National Science Foundation fields of doctorate awards and employment.

Forms and Reports: Questionnaire in 1975 report, Doctoral Scientists and Engineers in the United States--1975 Profile, National Research Council (NRC), Characteristics of Doctoral Scientists and Engineers in the United States, 1975, National Science Foundation. Both NRC and NSF have produced other reports from this data source.

Evaluation Commentary: This series of survey is the definitive one covering science and engineering doctorates; some professional societies survey selected populations. Sample size limits reliability for very small fields. However, sample can be enhanced to produce "better" data in selected cohorts. Data on computer tapes, thus additional tabulations can be obtained. Separate data on energy.

FEDERAL FUNDS FOR RESEARCH, DEVELOPMENT, AND OTHER SCIENTIFIC ACTIVITIES, FISCAL YEARS 1976, 1977, 1978--NATIONAL SCIENCE FOUNDATION

Agency: National Science Foundation
Unit: Division of Science Resources Studies

Description:

Content: Twenty-fifth annual report on Federal funds for R&D by: agency, character of work (R-D-Basic-Applied and R&D plant), performer (Department and Bureau), field of science (life sciences, electrical engineering--but no energy break), research at universities by agency and field of science, foreign performers (region, country, agency), geographic distribution by state. Historical data available on outlays and obligations 1967-77 (some from 1960).

Coverage, Survey Method, Sources, Sample: Mail survey forms to 35 Federal agencies and subdivisions (93 respondents) on obligations and outlays incurred for R&D. Information supplemented by Office of Management and Budget reports submitted by agencies on R&D activities and expenditures (as contained in OMB special analysis "P"--"Federal R&D Programs").

Reference Date: Fiscal Years 1976, 1977, 1978

Frequency: Annual

When Available: November 1977 (Statistical Tables).

Classifications: NSF fields of science and character of work.

Forms and Reports: Form not shown in report but obtainable from National Science Foundation represent 3 years estimates (revised and updated each year) for R&D by headings in this report. Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1976, 1977, and 1978, Vol. XXVI, NSF (in press). This volume includes PART I (R&D funds) and PART II (funds associated with collection and dissemination of scientific and technical info); contains analysis, charts, summary current and historical tables and is supplemented by Appendix volumes showing detailed statistical data. Detailed Statistical Tables (Appendices C and D) NSF 77-317.

Evaluation Commentary: There are potential substantial differences in response among agencies owing to imprecision of concept and judgmental decisions in classification. There are wide differences within agencies and among bureaus in identifying R&D and distinguishing one type from another, and among individuals within same unit in making such classifications for different reporting requirements or over time. Nevertheless, the series is probably still best indication of R&D funding magnitudes by Federal Government and for other distributions shown. Special identification of energy R&D is not obtained specifically from this survey, but is identified by NSF staff (see NSF-4).

FEDERAL R&D FUNDING BY FUNCTION

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: Federal obligations for R&D are classified by 15 major and 34 sub-functions (including "energy development and conversion"). Each set of R&D dollars is classified into a single function. Data available for fiscal years 1969-78 and classified by function and agency. Data are presented in 3-year series, with last 2 years estimated on basis of President's budget. Data also shown by substantial detail of programs within the sub-functions.

Coverage, Survey Method, Sources, Sample: Federal obligations classified by NSF staff using categories developed by National Science Foundation with aid of Office of Management and Budget. Obligations data were collected from agencies as responses to regular (annual) survey of Federal funds. Data classified by function on basis of detailed budget requests.

Reference Date: Fiscal year

Frequency: Annual

When Available: 9 months after President's budget.

Classifications: National Science Foundation for R&D and fields of science; National Science Foundation/Office of Management Budget: functions.

Forms and Reports: Annual Report On Analysis of Federal R&D Funding by Function 1969-78.

Evaluation Commentary: Practically full scale coverage of R&D funding by Federal agencies. Data not strictly comparable over years because of change in functional categories. Federal dollars classified into separate functional categories and thus no multiple classification is available. Separate data on energy provided.

ENERGY R&D IN FEDERAL INSTALLATIONS

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: R&D spending and R&D manpower in energy and energy-related programs in Federal installations. R&D dollars classified by energy source (oil, coal, nuclear, conservation, environmental control, etc.) by installation and agency. Personnel in R&D classified by broad occupation, energy source and selected installation. Projections of R&D dollars also made.

Coverage, Survey Method, Sources, Sample: Questionnaire survey mailed by NSF to Federal agencies involved in energy R&D. Survey was not on sample, rather it was for full coverage of agencies reporting intramural energy R&D activities in regular NSF survey of Federal R&D funding.

Reference Date: Fiscal years 1973-75

Frequency: Single time

When Available: One year after

Forms and Reports: Energy and Energy-Related R&D Activities of Federal Installations and Federally Funded R&D Centers (NSF 76-304).

Evaluation Commentary: This may have been a single time survey. It was conducted about the end of 1974--a period of planning and the early implementation of "Project Independence." Its coverage was fairly complete and reporting good. However, there are no present plans to conduct another survey--"pressure of priorities"--within NSF.

RESEARCH AND DEVELOPMENT IN INDUSTRY 1974

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: Latest (as of 9/76) in largely annual series (20th since 1953) on R&D expenditures in private industrial firms. Funds for R&D are given by: source, industry, size of company (sales and employment), geographic distribution, basic versus applied, energy and pollution abatement R&D (funds--no employment data), employment of R&D scientists and engineers by industry, Federally-funded R&D centers. Historical data shown to 1953 or 1964 for some series.
APPENDIX: Technotes, detailed statistical tables and survey form. Some additional detail of R&D employment by industry, cost per R&D scientist, percent of R&D employment to total employment, but no energy employment data.

Coverage, Survey Method, Sources, Sample: Mail survey of 1400 companies representing stratified sample of all manufacturing and non-manufacturing industries known to fund R&D. Survey unit = company. Standard error less than 1% on totals, up to 7% for industries, up to 47% for companies with under 1000 employees; substantial comparability over time, particularly adjacent years. Limited coverage on energy: funds shown for energy industries (but no employment) by Federal and company, for fossil (by fuel) nuclear (by fission or non-fission) and other energy (solar, geothermal).

Reference Date: Year 1974 (for $); January 1975 for employment

Frequency: Annual

When Available: September 1976 (Preface date)

Classifications: 1967 Standard Industrial Classification

Forms and Reports: Research and Development in Industry, 1974, NSF 76-322; Highlights -- Energy Increase of 18 Percent Leads Industrial R&D Spending in 1975, NSF 76-324. Forms RD-1, RD-3, RD-11 are reproduced in principal reports.

Evaluation Commentary: This survey (and its predecessors and related reports listed above) is the definitive measure of R&D spending and employment and establishes the order of magnitude of the totals and industry distribution (up to 5 digits Standard Industrial Classification for selected industry). One major weakness is that the reporting unit is a company rather than an establishment. Useful spending data on energy and anti-pollution industries (basically 2-digit SIC) are limited by lack of comparable manpower data or even basis for relating funds to employment. Inclusion of energy employment query in future surveys would be useful if even only one time, as would sub-sample asking for occupational detail. These would show magnitude dealt with now known only vaguely, give basis for relating future R&D funds in energy to manpower component, and identify principal occupations in now only surmised broad array of energy R&D occupations.

RESEARCH AND DEVELOPMENT IN STATE GOVERNMENT AGENCIES

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: A periodic survey of R&D activities of State Government agencies which collects information on a project basis of such activities including: name of project; character of work (basic, applied development); field of science; financial support by source (other agencies, industry, universities, etc.); expenditures for R&D plant; man-years of R&D employment of scientists, engineers, and technicians; support by Federal agency. Functional areas (health, natural resources, transportation, etc.) are identified by agency subdivision--but no energy area.

Coverage, Survey Method, Sources, Sample: Agencies of State governments identified from past surveys of National Science Foundation and Bureau of Labor Statistics and review by individual State budget officers. Mail questionnaires sent to State by Bureau of the Census under contract with National Science Foundation. Initial universe of 1309 units was reduced to 1276 as a result of reorganizations and phase-outs. Response was 98% with 41% of these indicating R&D activities. Last survey conducted covered fiscal years 1972 and 1973. Reporting of activities was by project within agency subdivision.

Reference Date: Fiscal year

Frequency: Periodic--3-4 years

When Available: 1 year after survey

Classifications: NSF fields of science and other categories

Forms and Reports: Research and Development in State Government Agencies, Fiscal Years 1972 and 1973 (questionnaire included in report), NSF 75-303.

Evaluation Commentary: Coverage of individual State agencies was good--98% of identified units. Unclear as to how and by whom units engaged in R&D were identified. Survey conducted only every 3-4 years leaves a significant gap in changes in State agency priorities for R&D. Energy was not really very visible in 1973.

EXPENDITURES FOR SCIENTIFIC ACTIVITIES AT UNIVERSITIES AND COLLEGES

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: Current expenditures for research and development in science and engineering by source of funds, character of work (basic and applied research, development), field of science, institutional control (public/private), type of institution (level of degree granted) geographic location, capital expenditures for research, development and instruction, and expenditures for instruction and departmental research in graduate-degree-granting institutions. Similar data are obtained for Federally-Funded Research & Development Centers (FFRDC's) administered by universities.

Coverage, Survey Method, Sources, Sample: Mail questionnaire survey in universities and colleges--all institutions granting graduate degrees in science or engineering and all others with $50,000 in R&D expenditures. The 1975 survey covered 540 universities and colleges and 22 FFRDC's--covering 99% of all R&D in academic institutions. Eleven schools did not respond but imputations were made for these institutions.

Reference Date: Fiscal year

Frequency: Annual (1975 was 10th)

When Available: About one year after survey

Classifications: National Science Foundation/Office of Management and Budget's fields of science; National Center for Education Statistics/National Science Foundation's classes of institutions.

Forms and Reports: Questionnaire included in primary report Expenditures for Scientific Activities at Universities and Colleges FY 1975 (also a companion report Detailed Statistical Tables for same survey). Data also are abstracted for use in National Patterns of R&D Resources (NSF-9).

Evaluation Commentary: This is the definitive survey collection on R&D spending in universities and colleges. The survey does not provide separate data on university R&D expenditures in energy areas, but provides the background totals for all R&D. A companion survey provides data on professional staff in science and engineering employed in universities and colleges (No separate data on energy). (See NSF-12.)

FEDERAL SUPPORT OF RESEARCH IN UNIVERSITIES AND NONPROFIT ORGANIZATIONS

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: Information on Federal support of research and research facilities in universities, colleges, and selected nonprofit organizations is computed by National Science Foundation from other Federal agencies. In addition, information is collected on all other scientific activities and nonscientific activities, e.g., instructional equipment, training grants and fellowships and general science support. Data are categorized by field of science, institution, agency, type of activity, geographic location; data are in terms of dollar allocations. The report is mandated under the enabling act of the Foundation.

Coverage, Survey Method, Sources, Sample: Data are collected from 14 Federal agencies representing an estimated 99% of all Federal R&D support and 95% of all Federal support to such institutions. Data are separated by each educational institution and are available on 122 selected nonprofit organizations and seven Federally-funded R&D centers.

Reference Date: Fiscal year

Frequency: Annual

When Available: About 1 year following close of fiscal year.

Classifications: National Science Foundation fields and categories of R&D

Forms and Reports: Annual report to President and Congress Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, FY 1974 (NSF 77-303).

Evaluation Commentary: Data cover obligations made by 14 agencies representing 99% of all Federal R&D support to such institutions. No separate data on energy.

RESEARCH & DEVELOPMENT SPENDING BY NONPROFIT ORGANIZATIONS

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: Research and development spending and employment by type of organization (research institute, museum, etc.). geographic location, level of education (of scientists and engineers). Also data obtained on capital expenditures for R&D, R&D spending by source of funds (Federal, foundations, etc.), and field of science. Data cover both intramural operations and awards made to others by these nonprofit organizations.

Coverage, Survey Method, Sources, Sample: Mail questionnaire to all nonprofit organizations possibly spending at least $100,000 annually on R&D. Covers research institution, voluntary hospitals, private foundations, associations and societies, etc. In 1973 survey, survey mailed to 664 organizations (some 220 removed as not applicable) and responses received from 294 or 66%--estimates made for 150 nonrespondents.

Reference Date: Fiscal year

Frequency: Periodic (3-4 years)

When Available: About one year after.

Classifications: National Science Foundation fields of science and categories of organizations.

Forms and Reports: Research & Development Activities of Independent Nonprofit Institutions, 1973 (questionnaire included), NSF 75-308.

Evaluation Commentary: Survey not conducted except as priorities allow -- every 3-4 years. Last survey was for FY 1973. Difficult to obtain and keep current possible universe, nonresponse substantial and estimates for nonrespondents questionable. No separate data on energy.

NATIONAL PATTERNS OF R&D RESOURCES: FUNDS AND MANPOWER

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: An annual compilation of data on R&D funding and scientific and technical manpower in R&D. Each report contains trends on these factors since data were first collected in various economic sectors, e.g., 1976 report contains 1953-76 information. All data are from annual and other periodic surveys of R&D undertaken by Science Resources Studies (NSF). Data are all in summary form, but include considerable detail by sector of economy, type of R&D, industry, and occupation.

Coverage, Survey Method, Sources, Sample: Coverage of sector and periodicity of data varies according to original sources of data. Industry and Federal Government (two largest sectors) are annual. However, this is the standard Federal and national source of information on R&D funding and manpower.

Reference Date: Varied, latest data

Frequency: Annual collection

When Available: Spring

Classifications: National Science Foundation classifications

Forms and Reports: Questionnaires for sectoral surveys are with each separate collection. Annual report is same title as series (latest is NSF 77-310).

Evaluation Commentary: Data limitations, comparability, etc., vary by sector. Evaluation commentary are included with individual sector surveys.

NSF 10

FEDERAL EMPLOYMENT OF SCIENTIFIC AND TECHNICAL PERSONNEL

Agency: National Science Foundation using data obtained from the Civil Service Commission (CSC)
Unit: Division of Science Resources Studies

Description:

Content: Employment of persons classified as scientists, engineers, technicians and in health fields by Federal agencies. Data classified by occupational categories, agencies, function (R&D) for some years, grade, and some geographic locations. A new reporting system will bring data on educational level (by field) and better reporting of work activities. Characteristics tabulated in the Central Personnel Data File (CPDF) include:
1) Civil Service Commission occupational series,
2) highest degree,
3) field of highest degree,
4) age,
5) function (shows R separate from D),
6) supervisory and management status (new as of June 1977),
7) sex,
8) minority status,
9) grade (or equivalent for non-graded),
10) agency (plus some subdivision),
11) state of employment,
12) salary plus some others, e.g., veteran.

Accessions and separations tabulation is from "Nature of Action" reports.

Coverage, Survey Method, Sources, Sample: Data secured by National Science Foundation from Civil Service Commission tabulations made from annual occupational survey (usually made around first of the year). Civil Service Commission has developed new reporting system on persons employed by Federal agencies using a "Central Personnel Data File" (CPDF). Present collection covers practically all agencies (except CIA, FBI and similar units) employing scientists and engineers.

Reference Date: January for annual survey; periodic for CPDF information.

Frequency: Annual

When Available: About one year

Classifications: Civil Service Commission occupational codes and grade levels.

Forms and Reports: Scientific and Technical Personnel Employed by the Federal Government, Education and Work Activities of Federal Scientific and Technical Personnel (NSF 76-308). Questionnaires used are Civil Service Commission report on occupational employment.

Evaluation Commentary: Practically full scale coverage of Federal employment. One limitation is that under old system of reporting, persons were classified under standard Civil Service Commission (CSC) occupational codes and, therefore, there was some underreporting of scientists and engineers employed by agencies (those in administrative jobs). New reporting system eventually may be on sample basis for large agencies. No separate reporting on energy--except for employment in Energy Research & Development Administration and Federal Energy Administration as energy agencies.

NSF 11

INDUSTRIAL EMPLOYMENT OF SCIENTISTS AND ENGINEERS

Agency: Bureau of Census for National Science Foundation
Unit: Census-Economic Surveys Division; NSF-Science Resources Studies Division

Description:

Content: Employment of scientists, engineers, and technicians by occupation, industry, and reporting by engagement in R&D activities. Separate reporting by energy sources and energy stages (exploration, refining, etc.).

Coverage, Survey Method, Sources, Sample: Mail questionnaire survey conducted by Census in mid-1975 for NSF. Sample design based on stratified groups (31 industries) divided into 5 employment sizes (altogether 109 strata). The total number of establishments chosen was about 27,000 (14,100 belong to 5358 multi-unit companies and 12,700 to single unit companies. Several follow-ups made. Response rate was low (about 69%).

Reference Date: March 1975

Frequency: Single time

When Available: Early 1977

Forms and Reports: National Science Foundation Highlights Private Industry Employment of Scientists and Engineers in 1975 Shows 5 Year Decline (NSF 77-312) and Current and Future Utilization of Scientific and Technical Personnel in Energy-Related Activities (NSF 77-315).

Evaluation Commentary: The survey was generally not successful. The response rate was low--less than 70 percent. There were also numerous problems with response to individual questions on the form, e.g., technician reporting and level of education of scientists and engineers. This survey of National Science Foundation/Census was to restart a program of collection on industrial employment on all scientists and engineers and those on energy work.

SCIENTISTS AND ENGINEERS EMPLOYED BY UNIVERSITIES AND COLLEGES

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: Full- and part-time employment of scientists, engineers, and technicians by universities and colleges and Federally-Funded Research and Development Centers (FFRDC's) run by them. Data available by field of employment, function (R&D, teaching and other), by highest degree attained, institution, geographic location, type of institution (level of degree granted, and type of control). Employed graduate students and post doctorates are included with separate data on former. Similar data are available back to 1965.

Coverage, Survey Method, Sources, Sample: Survey universe includes all higher education institutions (including 2-year schools) except schools of art, music, law, theology and others without programs in science or engineering. January 1976 survey mailed to 2210 institutions with 1915 (or 87%) responding. National Science Foundation imputed data for 295 nonrespondents using past reports and other surrogates. These estimates amounted to about 7 percent of total employment of scientists and engineers. Doctorate-granting institutions had response rate of 96%. Mail questionnaire used with some telephone follow-ups.

Reference Date: January (mid-academic year)

Frequency: Annual

When Available: About one year after survey

Classifications: National Science Foundation fields of employment and fields of science, level of degrees.

Forms and Reports: Manpower Resources for Scientific Activities at Universities and Colleges, Jan. 1976 (NSF 77-308) plus a report with detailed statistical tables for each year.

Evaluation Commentary: Beginning in January 1975, survey mailed to nearly all institutions; prior to that, smaller institutions (in terms of degrees granted or R&D$) were sampled. Survey now provides comprehensive reporting of this segment of scientific and technical employment. No separate data provided for energy activities.

GRADUATE SCIENCE STUDENT SUPPORT AND POSTDOCTORALS

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: Numbers of graduate science students and postdoctorals and/or research associates in all science Ph.D granting institutions are reported by departments (also 105 medical schools). Data given by department, level of study, mechanism of support (fellowship, traineeship, etc.), source of student support (Federal agency, institution, foreign, self and family, etc.) for full-time students. Postdoctorals and research associates are shown by department and source of support. Counts of part-time students (not by support) also given.

Coverage, Survey Method, Sources, Sample: Data collected in fall 1976 for 1482 masters and 6289 doctorate level departments in science and engineering in 361 Ph.D granting schools (including 105 medical schools) and 1504 departments in 326 master's granting institutions. Schools granting less than doctorate in science and engineering not covered. The main survey is preceded by small sample "quickie" survey to give preliminary measure before end of calendar year of numbers of students enrolled.

Reference Date: Academic year

Frequency: Annual

When Available: Main survey results about 9 months after collection.

Classifications: National Science Foundation fields of science categories.

Forms and Reports: NSF data released in series Science Resources Studies Highlights. Full data released in reports on Detailed Statistical Tables (see NSF 77-319, in press). Questionnaire and instructions in reports.

Evaluation Commentary: Survey beginning in 1975 covers all institutions granting master's or doctorate degrees in science or engineering. Does not show any data by energy categories--only standard NSF field breaks. Data do not compare directly with National Center for Education Statistics data on graduate students because of coverage and fields.

1972 PROFESSIONAL, TECHNICAL, AND SCIENTIFIC MANPOWER SURVEY (POSTCENSAL SURVEY)

Agency: National Science Foundation (NSF)
Unit: Division of Science Research Studies

Description:

Content: Demographic, educational, professional and employment-related characteristics of scientists, engineers and technicians and persons with training in these fields identified through the 1970 Census of Population. Survey covered two time periods--1970 and 1972--employment, education and professional data including employment status, occupation, industry, and work activities of employment, field of education and level of degree, student status, marital status, sex, age, place of birth, etc.

Coverage, Survey Method, Sources, Sample: A national sample of over 150,000 persons was selected from records of the 1970 Census. These persons were coded by the Census in the experienced civilian labor force in scientific, engineering, technical and related occupations. In addition, a small sample of persons with 4 or more years of college, but in other occupations, was also included. Mail questionnaire used by the Census resulted in approximate 70% response rate. Full description of survey methodology, questionnaire, sampling, etc. is shown in reports listed below.

Reference Date: 1970 and 1972

Frequency: Single time (subsequently redesigned and conducted biennially as National Sample of scientists and engineers. See NSF 15.)
When Available: 1974

Classifications: Census occupations; NSF categories of fields.

Forms and Reports: Questionnaire included in primary reports. Primary reports issued were Selected Characteristics of Five Engineering and Scientific Occupational Groups, 1972, NSF 73-306, The 1972 Scientist and Engineer Population Redefined, (2 volumes and appendix), NSF 75-313 and 75-327. Census published two reports on the survey which include information on the methodology and sample: Persons in Engineering, Scientific, and Technical Occupations: 1970 and 1972, Current Population Reports P-23 No. 45, and Characteristics of Persons in Engineering and Scientific Occupations: 1972, Technical Paper No. 33.

Evaluation Commentary: Includes only persons originally included in sample from 1970 census; therefore excludes new entrants past that point. Sample for most major occupational groups generally large enough for most analyses with one exception. The sample was too small for the group of persons with 4 or more years of college but not currently (1972) working as scientists and engineers. The total sample, however, is the only national available group of persons trained in or working as scientists or engineers. The sample was surveyed again in 1974 and 1976 and will be resurveyed in 1978. See NSF-15. Separate data provided on energy involvement.

NATIONAL SAMPLE OF SCIENTISTS AND ENGINEERS

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: This is a series of surveys of a national sample of scientists and engineers based on the 1972 Postcensal survey conducted by Census for NSF. Surveys will be conducted every two years beginning 1974. Survey questions include educational attainment since 1971, work status for January of each of two years, occupation, location of work, work activities, salary, sponsorship under federal funds, and employment on national programs, including energy.

Coverage, Survey Method, Sources, Sample: The sample was that used in 1972 Postcensal which in turn was based on or drawn from the 1970 Decennial Census (1972 sample was 150,000 persons). Based on responses to the 1972 survey and criteria established by National Science Foundation, about 51,000 persons were surveyed in 1974. Mail questionnaires were used. Completed questionnaires were received from 44,000 or 87.7%. The survey, methodology sample, and coverage, are discussed in the primary report on the 1974 survey.

Reference Date: Spring

Frequency: Biennial

When Available: About one year after survey.

Classifications: Census/National Science Foundation occupations, degrees, industries.

Forms and Reports: Survey questionnaire included in reports. Characteristics of the National Sample of Scientists and Engineers, 1974, NSF (Part 1-Demographic and educational; Part 2-employment; and Part 3-geographic), NSF 75-333, 76-323, and 76-330. Several other related National Science Foundation reports, Selected Characteristics of Persons in Fields of Science and Science and Engineering, 1974 and Current Population Reports, Special Reports, P-23, No. 53.

Evaluation Commentary: The original Postcensal survey represented 1,400,000 scientists and engineers. After accounting for those who did not meet National Science Foundation criteria, did not respond, died, or moved out of science and engineering, some 1,080,000 scientists and engineers were represented in the 1974 survey. The technical notes in the main survey report (regarding above) contain discussions of methodology, sampling, limitations, weighting and estimating, and standard errors. The National Sample surveys are the only current collections covering this large a proportion of all scientists and engineers. However, its main limitations are the lack of new entrants since 1970. Separate data are provided on energy involvement.

IMMIGRATION OF ENGINEERS AND SCIENTISTS

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies, using data from the Immigration and Naturalization Service (INS)

Description:

Content: Information on the numbers of persons becoming or entering the U.S. as immigrants, who were also classified as scientists and engineers, is obtained by NSF from the Immigration and Naturalization Service (INS). Persons are classified as scientists and engineers on the basis of their declaration on their visas. However, their employment status and occupation in the U.S. is not determined. Information available on these persons includes year of entry or change of status, country of origin, country of last permanent residence. Data are available in various degrees of completeness for more than 15 years.

Coverage, Survey Method, Sources, Sample: The sources of data for numbers of persons obtaining immigrant status are several. The primary group is those persons entering the U.S. on immigrant visas, intending to become permanent residents. In addition, substantial numbers from foreign countries already in the U.S. change to immigrant status. These include students, temporary visitors, etc. The raw data on immigrants is furnished by INS to the NSF which analyzes and publishes information on the subject. The only "questionnaire" used is the application for immigrant visa or a similar form.

Reference Date: Fiscal year

Frequency: Annual

When Available: One year after close of fiscal year.

Forms and Reports: The National Science Foundation (NSF) periodically releases special tabulations and analyses through the two series, Highlights and Reviews of Data on Science Resources, and by other reports. The last release of information was in February 1977, which contained information for the period 1966-75, Scientists and Engineers from Abroad: Trends of the Past Decade, 1966-75 (NSF 77-305). Also, see Annual Report of Commissioner of Immigration and Naturalization (INS 1) and (NSF 19).

Evaluation Commentary: The information on numbers of persons entering the U.S. as permanent immigrants or changing status to immigrants obtained by the NSF from INS is almost complete. However, the data on occupation of immigrants is questionable. First, the original classification is based on immigrant declaration of occupation within country of origin. Second, there are no data on the current employment status or occupation of these persons, e.g., one can enter as an "engineer" but never be employed--as an engineer or anything else. The flow of immigrants over the years has varied in terms of totals, occupations, and country of origin as immigration policies changed. One important policy has been the restriction based on unemployment problems in the United States. Immigrants can enter under special occupational preferences only if their presence in the U.S. doesn't impact on employment chances for U.S. citizens. Illegal immigration, which is believed to be substantial, is not covered, of course. It is likely, however, that relatively few scientists and engineers come in illegally; more may change status on a questionable basis once they have entered as students or temporary visitors.

RESEARCH AND DEVELOPMENT IN LOCAL GOVERNMENTS

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: Surveys of these activities were made covering Fiscal Years 1966 and 1967 and Fiscal Years 1968 and 1969. These collections were made by the Bureau of Census for National Science Foundation. Local government units reported on a separate project basis the following: name and description of project; character of work (basic, applied, etc.); field of science; source of funds (Federal, State, local, etc.); R&D plant; and amount of R&D performed by other organizations. Separate data were obtained also on man-years of R&D employment for scientists and engineers, technicians, and all other personnel.

Coverage, Survey Method, Sources, Sample: A universe of the more than 80,000 local governmental units was used in this collection. The sample was stratified by six types of units--municipalities, counties, independent school districts, special districts, hospital districts, and townships--and by size of units (counties with 250,000 population, 100 largest hospital districts in terms of expenditures). In all, 713 independent units and 307 dependent agencies of larger units were mailed questionnaires.

Reference Date: Fiscal Years

Frequency: Periodic (last for 1968 and 1969)

When Available: One year after collection

Forms and Reports: Research and Development in Local Governments, Fiscal Years 1968 and 1969, NSF 71-6. (Similar report covering FY 1966 and 1967.) Questionnaires and instructions are included in reports.

Evaluation Commentary: The survey was fairly successful in terms of coverage of units and data collected. A new survey covering FY 1977 is in planning by NSF and Census. The 1968/1969 survey accounted for a total of $40 million (about one-half of which was supported by Federal funds) and about 2,600 full-time equivalent personnel (about 40 percent were scientists and engineers). Though this is an extremely small portion of total national R&D, this segment has not been measured since 1969. Also, no information on energy R&D activities has been collected for these agencies.

NEW ENTRANTS SURVEY OF RECENT COLLEGE GRADUATES

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: In 1976, this survey of bachelor's and master's degree recipients of academic years 1974 and 1975 was conducted by Westat, Inc. for NSF. Among the data collected were: age, sex, citizenship, race, date and field of degree received, employment status, general type of employment (business, education, government), work activity (research, teaching, etc.), employment on topics of critical national interest (health, defense, energy and fuel, etc.), support by Federal agency, and current student status.

Coverage, Survey Method, Sources, Sample: A two-stage sampling procedure was designed for this study. The first stage consisted of a sample of all colleges and universities offering a bachelor's or master's degree in science and/or engineering, producing 365 institutions for this study. From this sample, approximately 7,000 bachelor's degree holders and 1,000 master's degree holders were selected for each academic year. The sample of graduates was selected from computer-generated lists of graduates or graduation programs provided by the institutions. This material was secured through mail and telephone contact with each institution. Following the mailing of questionnaires, a number of follow-up strategies were employed to increase the response rate. Through these procedures, an overall response rate of 65 percent was achieved. The results of the survey were produced in computer-generated tables for analysis by NSF.

Reference Date: Academic year

Frequency: Periodic

When Available: About one year after survey.

Classifications: National Science Foundation and National Center for Education Statistics

Forms and Reports: A report on the survey is presently being prepared by the National Science Foundation. The questionnaire and methodologies used in the survey and other information will be included in the report.

Evaluation Commentary: The survey was generally successful although only a modest response rate was achieved. Westat is presently (late 1977) conducting a similar survey for the National Science Foundation covering the bachelor's and master's degree recipients of academic year 1972 and 1976. The former year is being surveyed to obtain an analysis of outcomes five years after award of degree.

Information obtained through these surveys will help to fill in the gap of new entrants in the NSF Survey, National Sample of Scientists and Engineers.

IMMIGRANT SCIENTISTS AND ENGINEERS IN THE UNITED STATES -A STUDY OF CHARACTERISTICS AND ATTITUDES (NSF 73-302)

Agency: National Science Foundation (NSF)
Unit: Division of Science Resources Studies

Description:

Content: This survey represents one of the rare attempts to obtain major follow-up information on immigrant scientists and engineers. Data were collected on: a) reasons for immigrating to the U.S., b) demographic characteristics, c) education, d) employment, e) publications and patents, and f) appraisals of living and working conditions in the U.S. Most information is tabulated by country of birth and/or country of last permanent residence.

Coverage, Survey Method, Sources, Sample: Based on a sample of immigrants, drawn from records of six field offices of the Immigration and Naturalization Service (INS), who reported themselves employed as scientists and engineers in the annual report required from aliens in January 1969. The size of the survey universe sampled for the specified scientists and engineers is not precisely known, but is assumed to correspond to the proportions of all immigrants covered by the six INS field offices sampled (namely, 30 percent). The sample covers aliens who became immigrants between February 1964 and January 1969. Sample frame is described in Technical Notes in the published bulletin.

Reference Date: Mid-1970 survey status of aliens reporting in the January 1969 annual alien survey, working as scientists or engineers, who became immigrants between February 1964 and January 1969.

Frequency: Single time

When Available: February 1973

Forms and Reports: Survey form is reproduced in bulletin.

Evaluation Commentary: This report represents a unique and valuable source of information on qualifications, contributions, employment status attitudes and reasons for immigrating to the U.S., of immigrant scientists and engineers. The report is, however, flawed because of difficulties in availability of initial records, errors in sample selection and coding and a lack of precise information on the size of the universe represented by the sample. Most important, the survey approach precluded assessment of information on immigrant scientists and engineers, based on their occupation prior to, and after, admission to the U.S. This survey started with the occupational designation of immigrants already in the U.S.

In addition to the important information developed, the ~~survey~~ undoubtedly resulted in improved record keeping by the INS and a generally keener interest in information on immigrants as a significant source of scientists and engineers in the U.S.

THE ENDICOTT REPORT: TRENDS IN EMPLOYMENT OF COLLEGE AND UNIVERSITY GRADUATES IN BUSINESS AND INDUSTRY (ALSO KNOWN AS NORTHWESTERN UNIVERSITY SURVEY)

Agency: Northwestern University, Evanston, Illinois
Unit: The Placement Center

Description:

Content: Company intentions as to hiring of graduates for the next year, and actual performance in the past year: number hired and to be hired, by sex, and salary level, tabulated by occupational specialty (see below), and by degree level. Also, monthly earnings of men in engineering and a few other fields who graduated 5 and 10 years ago; turnover rate in first 3 years for engineers and some other fields; factors determining needs (non-statistical).

Coverage, Survey Method, Sources, Sample: Personnel executives of 160 large national companies are surveyed each fall. Tabulations compare expected hirings next year with actual hirings last year, showing intentions compared to performance. Tabulations of starting salaries to be offered show distribution of offers by salary level, by degree level and field of degree, compared to averages paid last year. Median rates of turnover in each year of the first 3 are shown in the report; only half the companies report turnover.

Reference Date: November

Frequency: Annual

When Available: December

Classifications: Engineering, Chemistry, Mathematics/statistics, and 6 non-technical fields.

Forms and Reports: Annual report with title as above.

Evaluation Commentary: Intentions, if accurately reported, are useful information when compared to actual hires in the previous year. It would also be useful to know the actual hires and salaries paid by the end of each year compared to the intentions expressed in the previous fall. This might indicate the state of the labor market.

The sample is, of course, not representative of smaller companies, universities, and government, which together offer jobs to a large number of graduates.

OECD 1

INTERNATIONAL MEASURES OF RESEARCH AND DEVELOPMENT

Agency: Organization for Economic Cooperation and Development (OECD)
Unit: Directorate for Science, Technology, and Industry (DSTI)--Science Resources Unit

Description:

Content: Summarization of data obtained from various OECD members covering available measures of R&D since 1973 (same data up through 1976). Same 24 countries are included in study which is conducted about every 2 years. Spring issue of DSTI Newsletter accents data on Government funding of R&D including information on energy R&D dollars. Main biennial surveys include coverage of R&D spending and dollars in all sectors of member nations.

Coverage, Survey Method, Sources, Sample: OECD members are requested to complete questionnaires using available national information. Surveys usually conducted biennially. No sample involved--coverage of country surveys is equal to responses which may vary each survey period. Also each nation does not update each 2 years.

Reference Date: Calendar year

Frequency: Biennial

When Available: 1-2 years after reference year

Classifications: OECD Manual on standard survey practices

Forms and Reports: Biennial reports on OECD R&D surveys are available for 1963-64, 1967, 1969, 1971, and 1973. Also OECD publishes The Measurement of Scientific and Technical Activities - Proposed Standard Practice for Surveys of Research and Experimental Development (Frascati Manual).

Evaluation Commentary: Study is usually summation of R&D survey results from member nations. Thus, no new data on U.S. R&D activities is obtained through this mechanism. However, this activity provides international comparisons of R&D program expenditures for energy, but no manpower data are available.

INVENTORY OF ENERGY RESEARCH AND DEVELOPMENT

Agency: Oak Ridge National Laboratory, Energy Research and Development Administration (ERDA)
Unit: Energy Inventory

Description:

Content: Separate project reports as indicated by industrial and other performers. Each project of $5,000 or more was to be reported including information on location and type of organization performing R&D work, type of industry, number of full-time equivalent (FTE) scientists and engineers, type of sponsoring organization, expenditures for R&D by time period and phase of R&D work, field of energy R&D (coal, petroleum, electric power, etc.).

Coverage, Survey Method, Sources, Sample: The 1973-75 survey which was the most complete of 3 surveys undertaken reported on about 6500 projects totaling $2.5 billion in 1975. Source lists of industrial respondents were obtained from directories, lists of various Government agencies for contracts and surveys. It is not known how complete response was because of unclear instructions for cut-off and lack of an established universe. However, Oak Ridge National Laboratory (ORNL) states that 80-85 percent of all energy R&D performed in U.S. in 1973 was covered. A new survey is under way.

Reference Date: Years 1973, 1974 and 1975

Frequency: Every 3 years

When Available: 6 months after end of collection

Classifications: Standard Industrial Classification industries, ERDA energy R&D categories

Forms and Reports: Examples of questionnaires and instructions are shown in published reports. Results of survey are contained in 5 volumes released by Subcommittee on Energy Research, Development, and Demonstration of House Committee on Science and Technology, Inventory of Energy R&D, 1973-75.

Evaluation Commentary: Though survey was conducted by ORNL with sponsorship of House Committee and supported by ERDA and the National Science Foundation and though response was high, there is no way to determine its coverage or completeness. The 1973-75 survey specifically does not include demonstration as a phase of R&D, but it appears that a good many of these ERDA projects were covered--in terms of dollar amounts of expenditures for the energy projects listed. A 1976-78 survey is under way. However, it will not be a comprehensive approach. It is understood that ORNL will sample firms in a few areas. Also, the first draft of the questionnaire included a separate categorization of "demonstration" as a phase of R&D. However, it was decided to remove this category and stick with R&D as originally defined.

THE BITUMINOUS COAL INDUSTRY: A FORECAST, MANPOWER, GOVERNMENT POLICY, TECHNOLOGY

Agency: Pennsylvania State University, Institute for Research on Human Resources

Description:

Content: Using U.S. Bureau of Mines (BOM) projections of coal output, this report estimates associated manpower supply and demand. Aggregate manpower demand shown by surface and underground mining, estimated supply and new entrants required; projected employment by State.

Extensive analysis of productivity, composition of labor force, energy policy options, potential labor shortages, trends in mining technology and development and general industry outlook--no detail on skilled labor or R&D requirements.

Coverage, Survey Method, Sources, Sample: Sponsored by the Bureau of Mines, demand projections based on BOM output projections converted to State outputs assuming output per man at given wage; supply estimates based on econometric models of "competitive labor market," industry outlook--production methods, types of mining, consumption patterns, etc. Based on "Delphi method," i.e., opinions of experts which they are permitted to revise after learning opinions of each other, brought together to express a consensus or range of consensuses.

Reference Date: 1973 actual, 1985 and 2000 projected

Frequency: Single time

When Available: April 1975

Forms and Reports: No survey or forms, but gives extensive description of forecast techniques used.

Evaluation Commentary: Although totally lacking in direct reference to R&D manpower, the lengthy analysis of technology and output and use problems permits reader to make a rough approach to generation of estimates of change in current R&D manpower in coal mining industry.

SALARIES OF SCIENTISTS, ENGINEERS AND TECHNICIANS...A SUMMARY OF SALARY SURVEYS

Agency: Scientifc Manpower Commission

Description:

Content: A compendium of 138 tables on salaries of Scientific and Technical Personnel as collected by Government agencies, educational associations, magazine publishers and professional societies. Data organized and briefly described under headings of: 1) starting salaries; 2) salaries of experienced scientific and technical personnel; 3) salaries of engineers; 4) salaries of engineering technicians and technologists; 5) Federal salaries; 6) academic salaries.

Coverage, Survey Method, Sources, Sample: 24 sources are given for the 138 salary tables. Brief descriptions of data trends and significant findings are given under the six headings above. No description is given of energy methods, instruments, sample, etc. and only occasional reference is made to coverage.

Reference Date: Various (latest data for some tables is June 1977)

Frequency: One time summary

When Available: October 1977

Forms and Reports: Not described

Evaluation Commentary: A useful compendium of salary data on scientific and technical personnel based on disparate sources of varying degrees of reliability not adequately described.

THE AMERICAN FRESHMAN: NATIONAL NORMS

Agency: University of California Cooperative Institutional Research Program, Los Angeles (CIRP) and American Council on Education (ACE)
Unit: Laboratory for Research in Higher Education

Description:

Content: Personal, professional and education characteristics, career choices, undergraduate majors, levels of degree sought and sources of financial support of freshmen in universities and colleges. These annual data offer a first look at the potential supply of college-trained personnel.

Coverage, Survey Method, Sources, Sample: The survey questionnaire is administered to freshmen in nearly 600 colleges and universities in 1976. Although 328,000 forms were returned, data on 216,000 from 393 institutions were used to calculatd the norms. All institutions in the National Center for Education Statistics/Higher Education General Information System survey are invited to participate. The "National Norms Data" are based only on data from institutions where the coverage of entering freshmen is judged to be representative, although information from questionnaires not used in these averages is supplied to the originating institutions for their own planning needs.

Reference Date: Fall

Frequency: Annual

When Available: 9 months after collection

Classifications: CIRP taxonomies

Forms and Reports: Questionnaire and description of methodology are included in published report. Annual report produced, The American Freshman: National Norms for Fall 1976.

Evaluation Commentary: Main purpose of survey is to collect descriptive normative information on entering students for a variety of analytical and administrative interests, and as a reference base for longitudinal follow-ups of these students to determine the effects of college on them. CIRP's interest appears to be mainly in the process of education rather than in career outcomes.

There still seem to be problems with the degree to which schools are representative of the entire structure. Sample is particularly weak in coverage of technical schools.

APPENDIX C

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APPENDIX D

LIST OF INDIVIDUALS INTERVIEWED*

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION (ERDA)

Headquarters

Theodore M. Albert	EDIN
J. F. Casey	LABR
Arthur G. Follett	GE
S. William Gouse	AFE
Lloyd D. Herwig	Solar
Edward L. Johnson	OC
James S. Kane	ASGA
John F. Kaufman	APAE
James C. Kellett	OUP
Richard H. Lewis	APAE
Edgar L. Lucas	OC
Ann G. Montague	LABR
Robert C. Stephenson	OUP
Robert A. Summers	AFO
Wayne W. Rives	LABR
John G. Yates	AFO

Field Installations

Argonne National Laboratory

Ralph P. Carter	Land Reclamation
L. Burris	Chemical Engineering
R. O. Ivins	Coal Program
N. Kostyk	Environmental Systems
M. C. Kyle	Environmental Planning
Leon Markheim	Public Affairs
R. G. Matlock	Solar Energy
C. Redmond	MHD
C. Roberts	Educational Affairs
R. E. Rowland	Radiological and Environmental

Bartlesville Research Center

John S. Ball	Director of Center

Fermi National Accelerator Laboratory

H. Hinterberger	Technical Services

Lawrence Berkeley Laboratory

Jack Bolger	Transportation
Robert Budnitz	Environmental
John Harte	Ecosystems
Craig Hollowell	Air Quality
Dean Merrel	Computer Science and Mathematics
Michael Wahlig	Solar
Carl York	Energy Conservation

* Most were by personal contact; a few were by telephone.

Oak Ridge Associated Universities	
Ron Gross	Manpower, Education, Research & Training

OTHER AGENCIES AND ORGANIZATIONS

Federal Energy Administration	
Lawrence Clinton	Energy Information and Analysis
B. D. Hong	Energy Information and Analysis
W. Richard Johnsen	Energy Information and Analysis
Batelle Memorial Institute	
Gerald Levy	Columbus Laboratories
Jean A. Newborg	Columbus Laboratories
College Placement Council	
Jean Kessler	
Department of Commerce	
Elmer S. Biles	Bureau of the Census
Department of Health, Education and Welfare	
Marjorie Chandler	National Center for Education Statistics
Theodore Drews	National Center for Education Statistics
Department of Labor	
Jerome M. Staller	Office of the Secretary
Willis Nordlund	Office of the Secretary
Brian McDonald	Bureau of Labor Statistics
Neal Rosenthal	Bureau of Labor Statistics
Dixie Sommers	Bureau of Labor Statistics
Anne Young	Bureau of Labor Statistics
Charles Green	Employment and Training Administration
Burman Skrable	Employment and Training Administration
National Planning Association	
Ivars Gutmanis	
National Science Foundation	
Joel Barries	Division of Science Resources Studies
Benjamin Olsen	Division of Science Resources Studies
William L. Stewart	Division of Science Resources Studies
Eleanor Stoddard	Division of Science Resources Studies
R. E. Kagarise	Division of Materials Research
Office of Management and Budget	
Charles Ellett	Statistical Policy Division
Milo Peterson	Statistical Policy Division
American Coal Association	
Joseph Yancik	Vice President for Research
Computer Sciences Corporation	
Chester Billingsley	