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manpower in energy-related activities

A Summary and Review of Recent Studies

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FOREWORD

Encouraging "individuals and groups in the private and public sector to produce and use energy resources wisely and efficiently" is an important objective of public policy, as described in The National Energy Policy Plan of 1981. To achieve this objective, a highly trained and motivated pool of engineers, scientists, technicians, and other workers must be available for research and development, teaching, exploration, production, and other activities.

The first section of this report provides an overview of current energy trends, national energy policies, and the employment response of workers in a variety of critical fields. In the second section, eleven recent studies of the supply of and demand for energy-related manpower are summarized and reviewed. These studies address a wide range of questions concerning current and future levels of employment, and potential shortages of workers, in various energy sectors.

Special recognition goes to Robert B. Garey, Sharon E. Bell, Joe G. Baker, Larry M. Blair, Michael G. Finn, and Wayne Stevenson of the Labor and Policy Studies Program, Oak Ridge Associated Universities, who are responsible for the analysis and for the preparation of this report.

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SECTION 1

SUMMARY OF CURRENT ENERGY-RELATED MANPOWER INFORMATION

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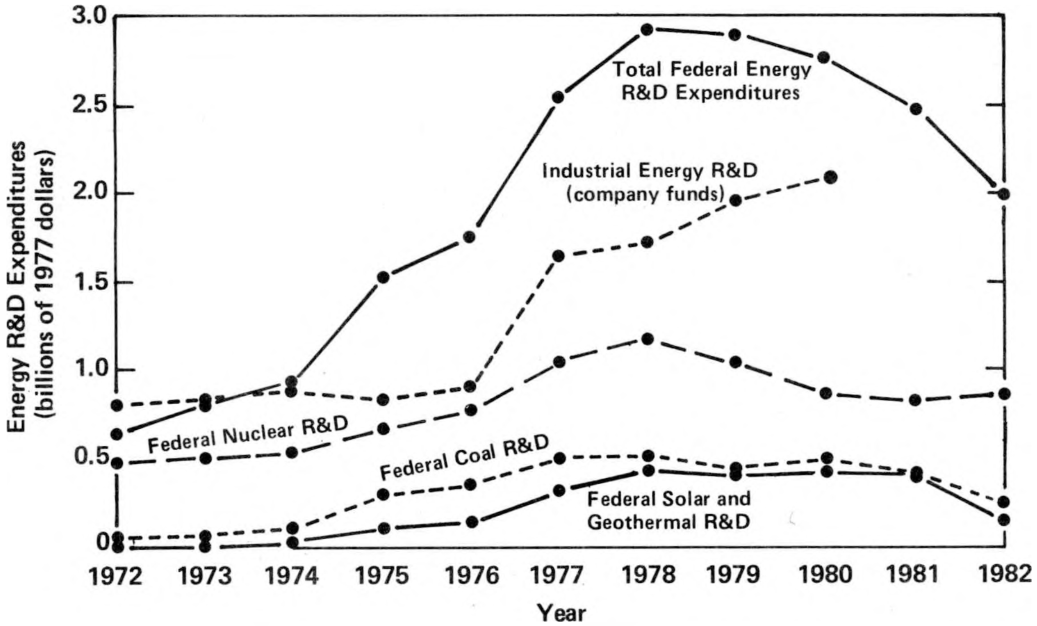
INTRODUCTION

The number of scientific, engineering, technical, and blue collar workers engaged in energy-related activities (research, development, exploration, production, conservation, etc.) in the United States has increased steadily since the middle 1970s. Much of this increase occurred as public and private energy research and development activities and funding were growing substantially between 1974 and 1979 (see Figure 1) and while the economy shifted toward greater reliance on domestic energy supplies and conservation efforts.

Figure 1. Federal Expenditures (in 1977 Dollars) for Energy Research and Development during 1972-1980, Budget Estimates for 1981-1982, and Industrial Expenditures of Company Funds for Energy Research and Development (in 1977 Dollars) during 1972-1979



Source: National Science Foundation, *An Analysis of Federal R&D Funding by Function* (Washington, D.C.: 1978); *Federal R&D Funding by Budget Function: Fiscal Years 1980-1982* (Washington, D.C.: 1981); and "Federal Funding by Budget Function: Fiscal Years 1971-1982" (unpublished).

Future energy-related employment trends will be influenced by a variety of developments. These include the rate of real economic growth, the extent of efforts to conserve energy, changes in conventional fuel prices, the level and success of public and private research and development activities, and many other political decisions and economic trends. For example, the recent decontrol of domestic oil prices during 1981 and the phasing out of natural gas price controls will likely continue to provide a stimulus for exploration and production employment in the petroleum and natural gas industry--despite sagging prices in the recent past.

Given the cautions expressed above, the demand for scientists and engineers involved in energy R&D--particularly related to technology development and commercialization--may be reduced. Federal funding (in 1977 dollars) for research and development in all technologies except nuclear energy has been decreasing in recent budgets and is expected to continue to decline in the near future (see Figure 1). Nuclear energy R&D is also scheduled for a decline in the proposed FY 1983 budget. Remaining federal energy R&D funds are being shifted toward research in areas such as basic energy sciences where the risks are high but the potential payoffs are great.[1] Some of the overall decline in federal energy R&D funding may be offset by increases in private sector efforts. After total federal expenditures (in 1977 dollars) for energy R&D peaked in 1978, industrial expenditures continued to increase through 1980, the last year for which data are available (Figure 1). However, uncertainty about future levels of public and private funding for energy R&D, and about the future of renewable-energy technologies, nuclear power production, and synthetic fuels adds to the complexity of estimating energy-related employment--especially for specific activities.

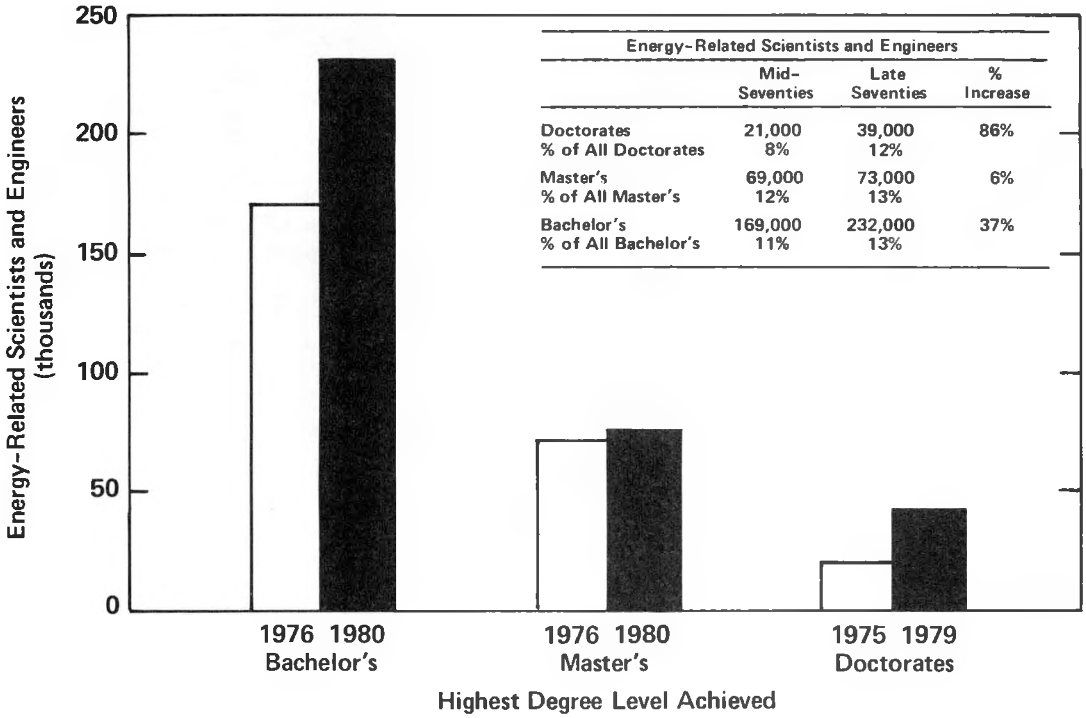
The first section of this report provides an overview of the relationships among current energy trends; national energy policies; and the employment of scientists, engineers, and (to a lesser extent) technicians, skilled craft, and other workers in each energy sector. Much of the general information offered and many of the questions raised in this section are addressed in depth in the eleven recent energy-related manpower studies summarized and reviewed in the second section.

SCIENTISTS AND ENGINEERS

Employment Trends

During the latter half of the 1970s, as federal funding for energy-related research and development was increasing, the number of scientists and engineers who indicated that their professional work activities were devoted to energy research, development, exploration, production, or conservation grew substantially. This is illustrated in Figure 2.[2] By 1979-1980, more than 340,000 (or about 12 percent) of the B.S., M.S., and Ph.D. scientists and engineers in the United States were engaged in energy-related work. The increases between the middle and late 1970s were greatest for those with bachelor's and doctoral degrees. At the bachelor's level, the number of scientists and engineers working in energy-related activities grew by 37 percent; while among those with doctorates, the number whose work was related to energy grew by 86 percent. By contrast, the number of M.S.-degree holders working in energy activities grew only 6 percent between 1975 and 1977.

Figure 2. Scientists and Engineers Working in Energy-Related Activities, by Highest Degree Level Achieved



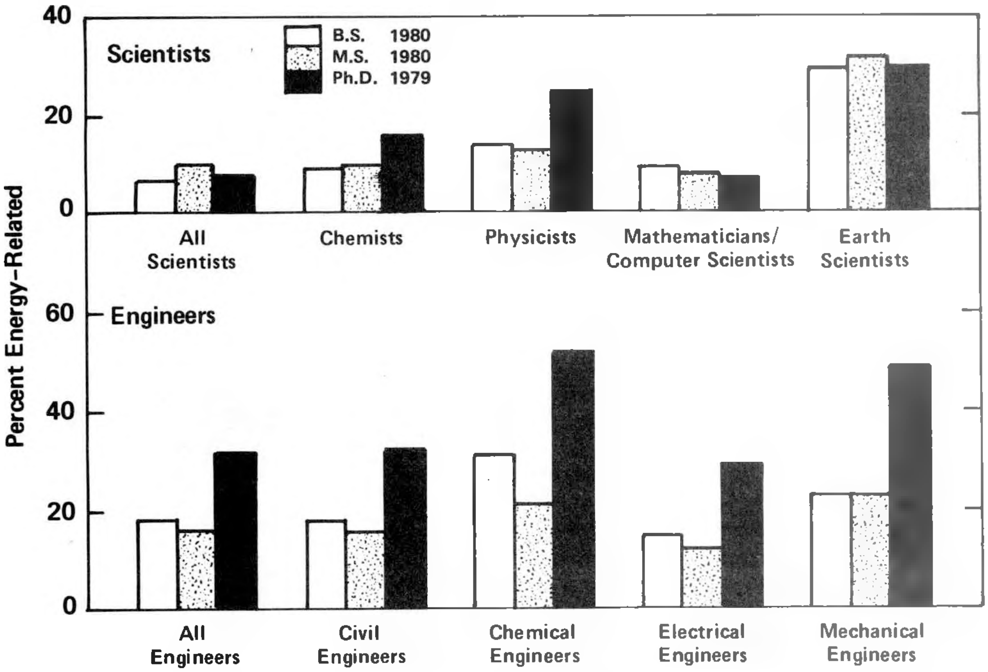
Energy-Related Scientists and Engineers

	Mid-Seventies	Late Seventies	% Increase
Doctorates	21,000	39,000	86%
% of All Doctorates	8%	12%	
Master's	69,000	73,000	6%
% of All Master's	12%	13%	
Bachelor's	169,000	232,000	37%
% of All Bachelor's	11%	13%	

Source: U.S. Department of Energy, Office of Energy Research, and National Science Foundation.

In general, a higher percentage of engineers than scientists worked in energy-related activities. Among the employment fields shown in Figure 3, the highest percentages of degreed workers whose professional activities were energy-related were in earth sciences and in chemical and mechanical engineering. Earth scientists and chemical engineers are used extensively in the petroleum/natural gas industry, while mechanical engineers are employed in substantial numbers in all energy sectors. Among certain smaller fields (such as nuclear, petroleum, or mining engineering), 60 to 80 percent are energy-related.

Figure 3. For Selected Employment Fields, the Percent of Scientists and Engineers Whose Work Was Energy-Related, by Degree Level



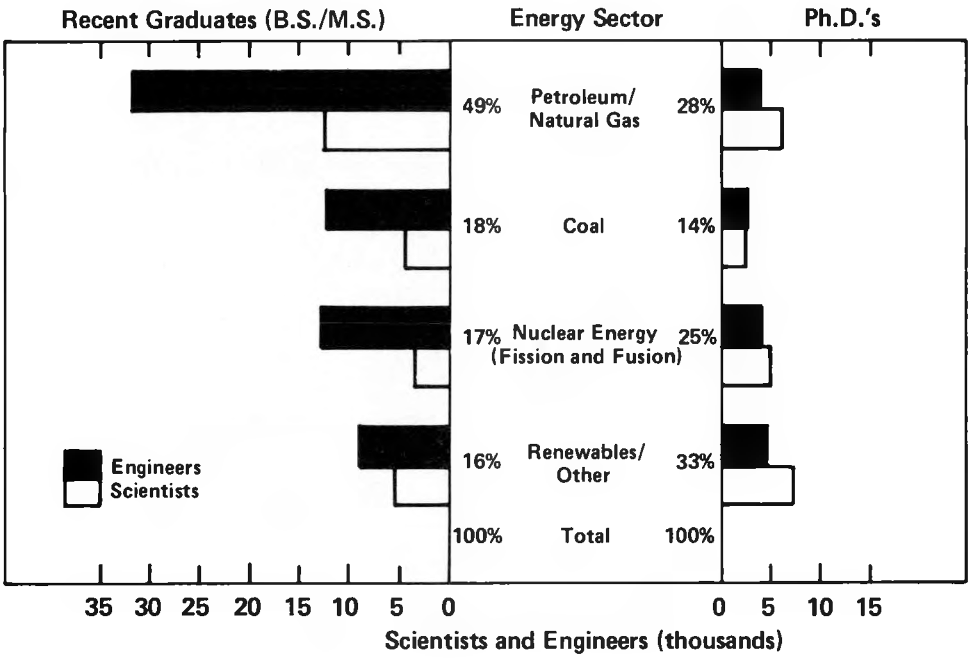
Sources: U.S. Department of Energy, Office of Energy Research, and National Science Foundation.

More scientists and engineers were working in the petroleum/natural gas sector than in any other energy sector in 1979 and 1980 (see Figure 4). Among Ph.D.'s working in energy-related activities, for example, more than one-fourth (28 percent) were concentrating on petroleum/natural gas. Another one-fourth of the energy-related doctorates were working in nuclear energy, while fewer were in the coal (14 percent), renewable (17 percent), or other (16 percent) energy technologies. No comparable information on the distribution of all B.S. and M.S. scientists and engineers across energy sectors exists. However, special surveys of those who received their bachelor's and master's degrees in the 1970s[3] indicate that almost one-half of those who found energy-related employment were in the petroleum/natural gas sector (Figure 4). The rest of these recent graduates were about evenly distributed among coal, nuclear, and renewable and other energy sources.

Little information is available on the number of foreign scientists and engineers employed in energy-related occupations in this country. A survey conducted by the National Research Council[4] indicates that 46 percent of the 1980 recipients of Ph.D.s in engineering in the United States were foreign citizens. Smaller percentages of those receiving doctorates in 1980 in mathematics (27 percent), the physical sciences (22 percent), and the earth sciences (17 percent) were foreign citizens. The number who had obtained employment by the time they graduated ranged from one-fourth of all foreign citizens receiving Ph.D.s in the physical sciences to slightly over one-half (56 percent) in engineering. The remaining foreign citizens receiving doctorates in these fields in 1980 either were still seeking employment or were entering postdoctoral study upon graduation. Of those with definite employment, a majority had found jobs within the United States, including 65 percent of those in engineering, 62 percent of those in mathematics, and 56 percent of those in the physical sciences
Only in the earth sciences did less than one-half (37 percent) of the foreign citizens with definite employment report that their jobs were in the United States.

Unfortunately, there are no available data on how long any of these foreign citizens will remain in this country after receiving their degrees. It is likely that at least some of those entering postdoctoral study will subsequently find jobs here, but the proportion is unknown. However, even some of those who reported having definite employment here can be expected eventually to return to their home countries--particularly since about half had only temporary visas. Of the 39,000 U.S.-employed, energy-related Ph.D.'s listed in Figure 2 who received their degrees between 1936 and 1978, less than 10 percent identified themselves as being non-U.S. citizens. No comparable information is available on the citizenship of B.S. or M.S. scientists and engineers educated or employed in the United States.

Figure 4. Number of Employed Ph.D.'s and Recently Graduated B.S. and M.S. Scientists and Engineers Working in Energy-Related Activities, by Energy Sector, 1979-1980



Source: U.S. Department of Energy, Office of Energy Research.

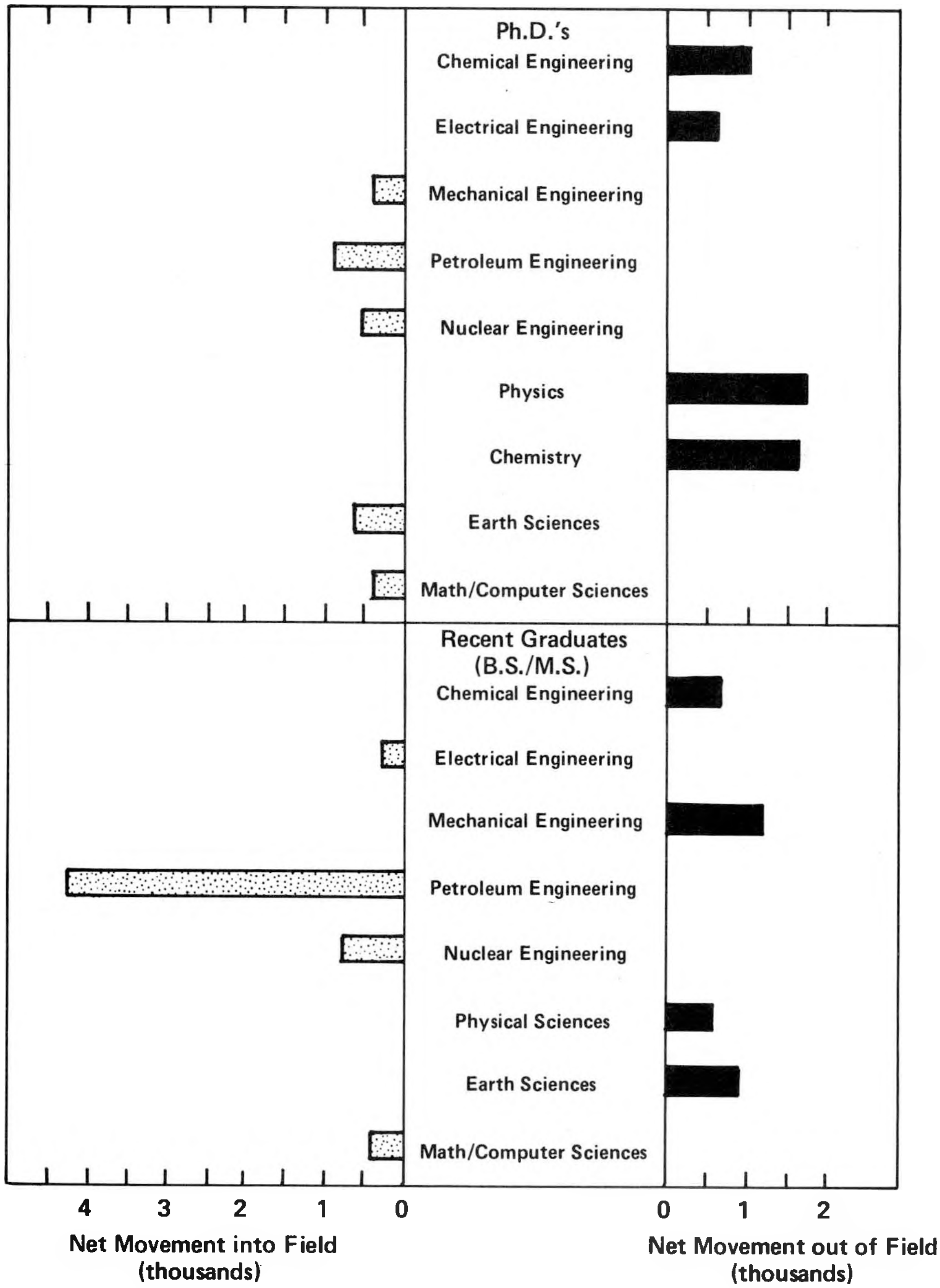
Field Switching

The employment of scientists and engineers in the petroleum/natural gas, coal, and nuclear energy sectors will increase substantially in the 1980s if forecasts by DOE's Energy Information Administration (EIA) and industry sources are correct.[5] Demand for personnel will be particularly intense in a few fields of critical importance to these energy industries. For example, earth scientists--especially geophysicists, geochemists, and geologists--will be needed in large numbers in the petroleum-natural gas industry as exploration for new fields and the drilling of both new and old fields increases.[6] Graduates in two specific energy-related engineering fields, petroleum/fuel technology and nuclear engineering, will also be needed in large numbers. If the demand for degree holders should exceed the available supply in these (or other) fields, salaries offered by employers will rise. The unfilled job positions and rising relative salaries may induce employers to hire scientists and engineers with education in related disciplines, although perhaps at the expense of lower productivity or increased training costs. As a consequence, few real shortages (positions left unfilled for long periods of time) of scientists and engineers can be expected even in fields in which demand is intense and increasing rapidly.

An indication of the amount of field switching that occurred in the late 1970s is found in Figure 5. Among both Ph.D.'s and recent B.S./M.S. graduates, there was a significant net movement into the petroleum/fuel technology engineering and nuclear engineering fields from other disciplines. Although the doctoral survey did not show which other engineering disciplines fed into these fields, it did indicate that about one-third of the Ph.D.'s with petroleum engineering jobs held degrees in chemistry and that one-fifth of the Ph.D.'s employed as nuclear engineers held degrees in physics. The recent B.S./M.S. graduates survey, on the other hand, showed that most of those switching into either petroleum or nuclear engineering came from mechanical, civil, and chemical engineering (often with some educational background in the petroleum or nuclear areas). Relatively few came from the physical sciences.

The Ph.D. survey also indicated a small net movement of personnel from other fields into the mathematics/computer sciences field. There was no clear pattern of disciplines "feeding" degree-holders into this field (mostly into computer sciences rather than mathematics). This is not surprising, since a strong background in computer applications is so essential in all of the science and engineering fields whose graduates are drawn heavily to energy research, exploration, and production. Finally, the doctoral survey results showed that a substantial number of Ph.D.'s switched into the earth sciences from other fields. This corresponds to the National Petroleum Council's finding that, in the late 1970s, many earth scientists in the petroleum industry--particularly geophysicists--were actually trained as engineers, computer scientists, and physicists.

Figure 5. Major Energy-Related Employment Fields and Size of Net Movement Into and Out of Each, 1979-1980



Source: U.S. Deparment of Energy, Office of Energy Research.

Type of Employer

From the middle to the late 1970s, most of the growth in energy-related employment for recent B.S. and M.S. graduates was in business and industry (from 26,000 in 1976 to 43,000 in 1979). The increase in energy-related employment for Ph.D.'s in business and industry from 1975 to 1979 was also very substantial (from 12,000 to 17,000). The most rapid growth in the number of Ph.D.'s working in energy-related activities, however, was in educational institutions (from 6,000 in 1975 to 16,000 in 1979),[7] while relatively few (less than 4,000) of the recent B.S. and M.S. graduates found energy-related employment in such institutions in 1979. Some of the energy-related scientists and engineers included in the employment totals for educational institutions were actually working in university-affiliated, federally-funded research and development centers (FFRDCs) such as Lawrence Berkeley Laboratory, Argonne National Laboratory, and Oak Ridge Associated Universities. Although the doctoral survey did not include a separate category for FFRDC employment, special DOE estimates suggest that between 2,100 and 2,500 Ph.D.'s were involved in energy-related activities in these centers. The total number of B.S. and M.S. scientists and engineers working in these FFRDCs was roughly one-third higher than the number of Ph.D.s.[8] However, there are no available estimates on how many of the FFRDC-employed B.S./M.S. scientists and engineers were involved in energy-related activities. Finally, at all degree levels there was a moderately large increase in the percentage of scientists and engineers employed by federal, state, or local governments whose work was energy-related, but the growth in absolute numbers was low.

While the recent increase in the number of Ph.D.'s involved in energy-related work in educational institutions has been quite dramatic, universities may still experience difficulty in educating enough graduates in the fields most important for energy R&D and production. The critical indication of whether universities will be able to produce sufficient numbers of scientists and engineers to work in energy industries is the trend in the total number of faculty members (energy-related and all other) in each discipline. The evidence from the Ph.D. surveys suggests that in some of the disciplines most directly tied to energy, the growth in faculty sizes may not have kept pace with the growth in teaching loads over the period. For example, the number of doctoral engineers in academic institutions (including those in university-affiliated FFRDCs) increased by only 10 percent between 1975 and 1979, while the number of B.S. degrees awarded in engineering grew by 50 percent.[9] Apparently, many engineering professors have been leaving universities for much higher paying positions in industry; and enrollments (and, consequently, degrees awarded) in doctoral programs have been declining because B.S. and M.S. graduates are also attracted into the private sector by rapidly rising salaries.[10]

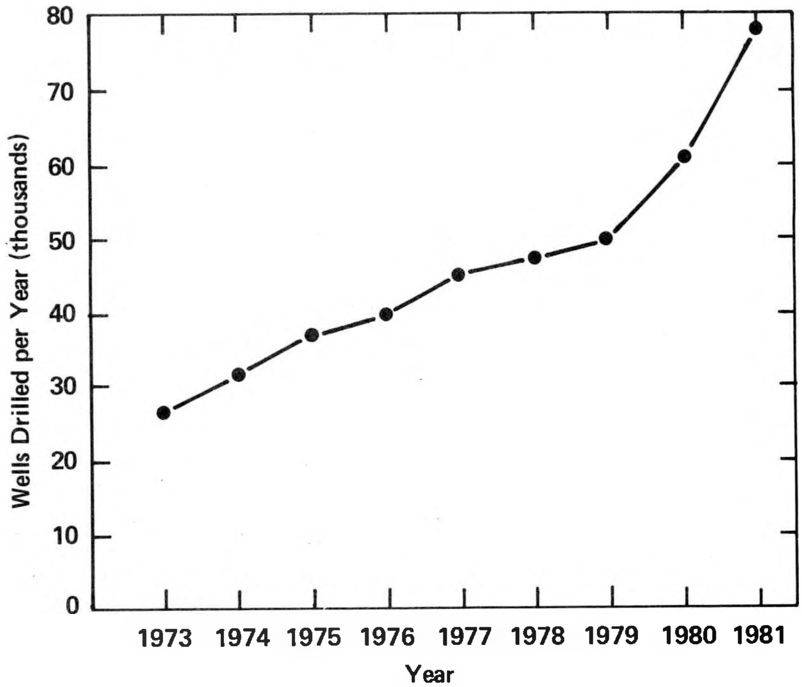
The percentage changes from 1975 to 1979 in the total number of faculty members varied by discipline, however. Like engineering faculties, mathematics and computer sciences, chemistry, and physics faculties grew slightly, while the number of earth science Ph.D.'s based in universities actually decreased in spite of rising demand for graduates in geophysics, geology, geochemistry, and other specialties in this field.

PETROLEUM AND NATURAL GAS

The tripling of both world and domestic oil prices since the early 1970s and even larger percentage increases in the price of natural gas have provided strong incentives for increased efforts by industry to find and extract these two sources of energy.[11] As a result, the total number of workers involved in oil and natural-gas extraction (including scientists, engineers, technicians, craft workers, clerical workers, and administrators), the number of seismic crews exploring for new fields, and the number of new wells drilled per year have all more than doubled since 1973 (Figures 6 and 7). Employment in support industries, such as the manufacture of oil-field machinery, also expanded greatly (from 50,000 in 1973 to 113,000 in 1981). However, since there has been only a slight increase in the production (and in the importation) of crude oil since the early 1970s, the number of workers in the oil refining industry has increased only 14 percent since 1973, as Figure 8 illustrates.

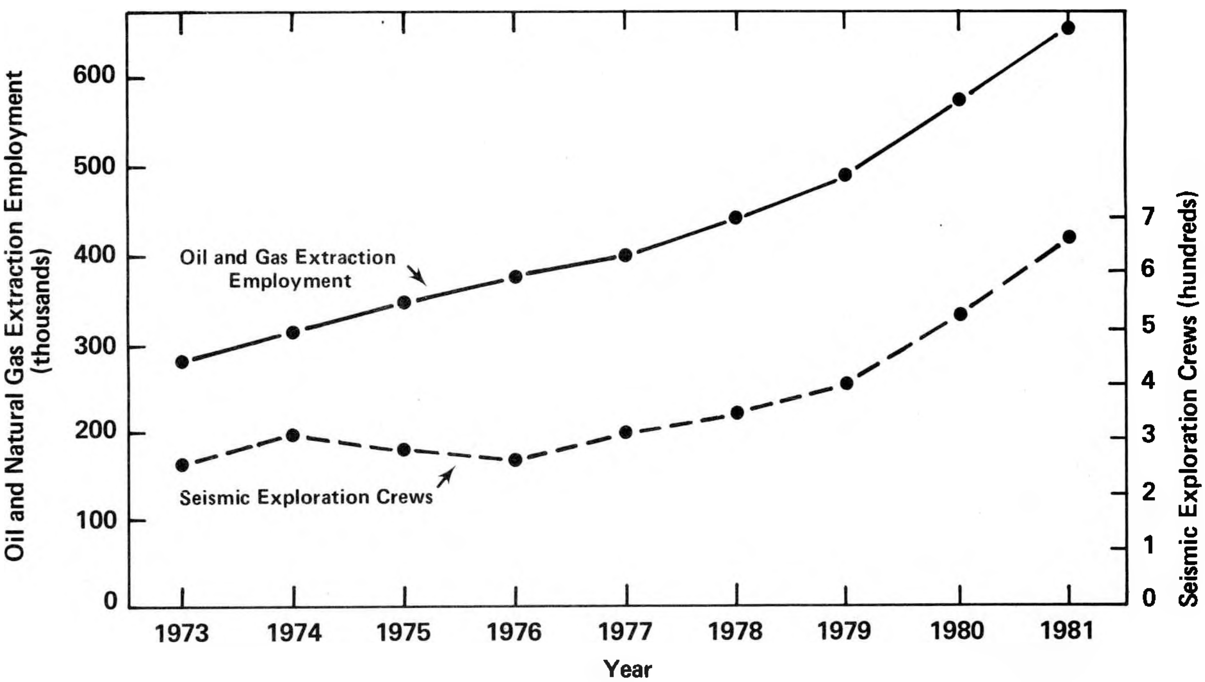
If the level of exploration and extraction activity should continue to increase in the 1980s, as projected in the 1979 report of the National Petroleum Council and the 1981 EIA *Annual Report to Congress*, the demand for degree holders in certain critical fields could temporarily exceed supply. For example, the number of openings for geophysicists, geochemists, and geologists needed to explore new and existing fields and for the engineers (particularly petroleum engineers) needed to prepare and drill wells could exceed the number of available graduates. In their 1979 projections of exploration and drilling in the 1980s, the National Petroleum Council estimated that these shortages would be short-lived. The production of graduates in these fields from universities has already begun to increase in response to the expanding employment demand and accompanying high salaries. In addition, the Council estimated that, at projected drilling activity levels, oil and natural gas companies would need fewer new scientists and engineers in these fields in the early 1980s after hiring large numbers in the late 1970s. Consequently, the Council projected that supply would once again exceed demand by 1982 or 1983.[12]

Figure 6. Number of Oil and Natural Gas Wells Completed, 1973-1981



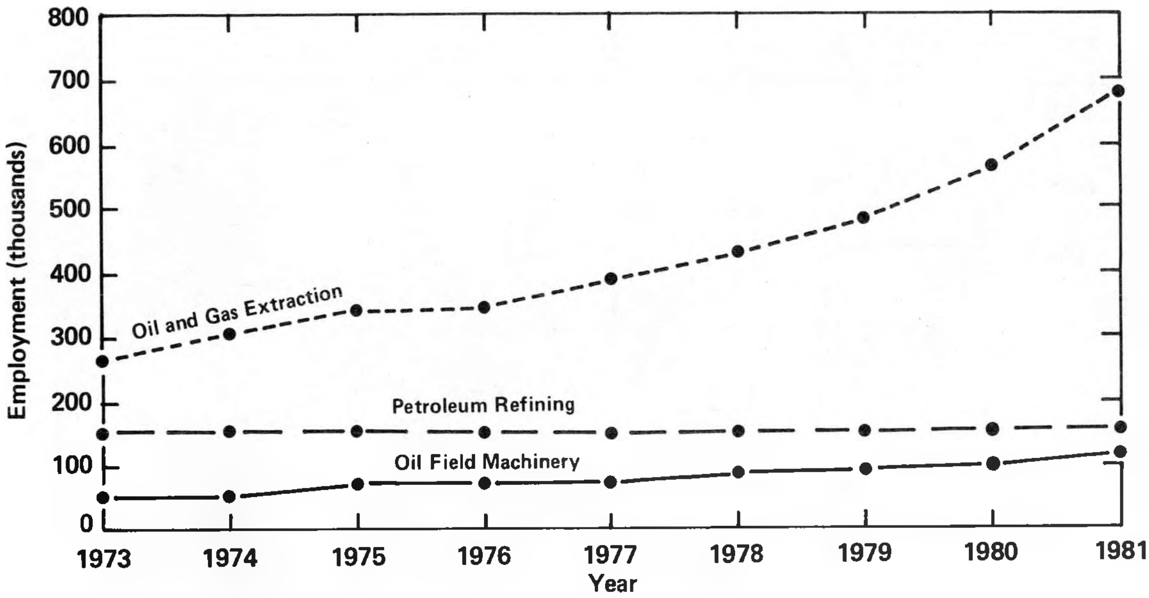
Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (February 1982).

Figure 7. Total Employment in Oil and Natural Gas Extraction and Average Number of Seismic Exploration Crews, 1973-1981



Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (February 1982); and U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Earnings* (September and October, 1974-1981).

Figure 8. Employment in Major Petroleum-Related Industries: Oil and Natural Gas Extraction, Petroleum Refining, and Oil Field Machinery Manufacturing, 1973-1981



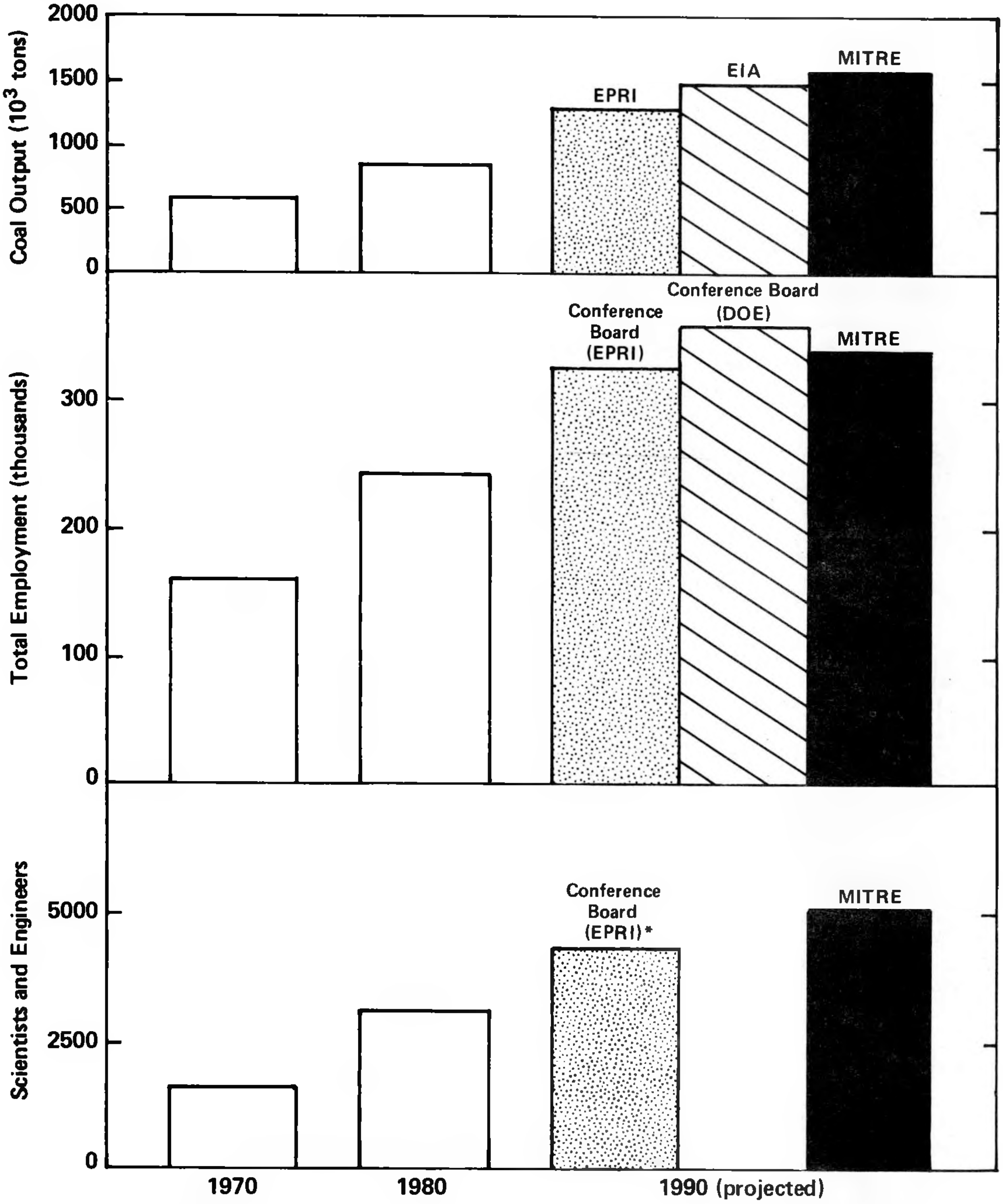
Source: U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Earnings* (September and October, 1974-1981).

Since the publication of these projections in 1979, however, the world price of oil increased substantially[13] and in turn drove up the domestic price of oil.[14] Moreover, the total decontrol of domestic oil prices has been completed (in early 1981). Average wellhead and residential natural gas prices, on a schedule of gradual decontrol through 1985, have also increased significantly (by 50 percent in real terms) since 1979. The economic stimulus of those rapid price increases and the expectation of further increases resulted in a level of drilling activity even higher than that projected by the National Petroleum Council[15]--at least through the fall of 1981 when gasoline prices to consumers began to sag. Nevertheless, even if these developments were to intensify demand more than previously expected, severe shortages in the industry in critical occupational fields would be unlikely. There is evidence to suggest that the high salaries common in the industry and the production bonuses and profit sharing offered by independent oil companies[16] are usually sufficient to attract professionals from related fields (such as chemical engineering, computer sciences, and physics) and from universities to fill these slots.[17] Moreover, according to the National Petroleum Council study, oil and gas companies are often able to avoid shortages by hiring at lower degree levels. For example, an "ample supply" of B.S. geologists is available to fill openings normally held for advanced-degree holders.

COAL

The price of coal has risen less than the price of other fuels since 1973, which has helped to increase coal demand and therefore production by over 40 percent. Concomitantly, the mining workforce increased by 55 percent, or from less than 158,000 in 1970 to more than 245,000 in 1980 (Figure 9). For various reasons, the demand for coal will likely be further stimulated in the 1980s. These reasons include the price advantage that coal enjoys over oil and natural gas in many regions and for various end uses,[18] the growth of coal export markets,[19] and the role of coal-fired power plants as electric utilities' chief alternative to nuclear reactors.[20] Also, some additional demand for coal may come from the slowly developing synthetic fuels industry in the late 1980s and 1990s. However, the amount will probably be much less than expected when the legislation establishing the Synthetic Fuels Corporation was passed in 1980, because the level of federal appropriations to the Corporation is much less than originally authorized, the price of crude oil has declined, and some private corporations have dropped major synfuels products. In a study reviewed in the second section of this report, the Institute of Gas Technology (IGT) estimated that the elimination of all federal funding for synfuels would reduce the number of coal gasification facilities to be built by the year 2000 from a high of perhaps 44 to as few as 6.[21]

Figure 9. Labor Requirements in Coal Mining, 1970-1990



* Engineers only.

Sources: Electric Power Research Institute, *The Labor Outlook for the Bituminous Coal Mining Industry* (Palo Alto, California: 1980); U.S. Department of Energy, Office of Energy Research, *Occupational and Training Requirements for Expanded Coal Production* (Washington, D.C.: 1982); and the MITRE Corporation, *Manpower for the Coal Mining Industry: An Assessment of Adequacy through the Year 2000*, 2 vols. (McLean, Virginia: 1980).

Future levels of employment in the coal industry will depend largely on the growth in coal output and on miner productivity levels (tons of coal produced per worker per year). These topics are the focus of several studies reviewed in the next section. The MITRE Corporation study, for example, projects future coal employment from a series of assumptions about factors expected to influence supply and demand. In what MITRE contends is the most likely growth scenario, coal output will reach 1.52 billion tons by 1990.[22]

Two studies by the Conference Board used a similar method to project future employment. In the first, sponsored by the Electric Power Research Institute,[23] the focus was on the availability of mining training resources. The study for DOE[24] used the Energy Information Administration's 1978 forecast of 1.47 billion tons of coal output in 1990 to project 353,500 total workers employed in the coal industry in that year. The more conservative EPRI estimates of 1.28 billion tons of coal output in 1990 result in projections of employment levels of 324,900 total workers and 4,300 engineers.

At the heart of these labor requirement projections are estimates of labor productivity. A report by Oak Ridge Associated Universities (ORAU)[25] found that industry regulation (health and safety and reclamation laws), work stoppages, and coal price inflation were major causes of significantly declining miner productivity in the 1970s. Using the ORAU results, the three studies discussed above (one by MITRE and two by the Conference Board, funded by EPRI and DOE) assumed that productivity would increase slowly in the future.

The EPRI-funded Conference Board study extended the labor analysis to examine new entrants into coal mining. From estimates of worker separation caused by attrition (workers dying, retiring, or leaving the industry) and from estimated growth needs, the study determined that approximately 51,000 new workers are needed annually to meet EPRI coal output forecasts. Many of these new workers (25,000) will be needed for replacement positions in eastern fields, where little growth in output is expected. The provision of technical, health, and safety training to these new miners presents a challenge to existing training resources, such as company programs and two year colleges.

NUCLEAR POWER

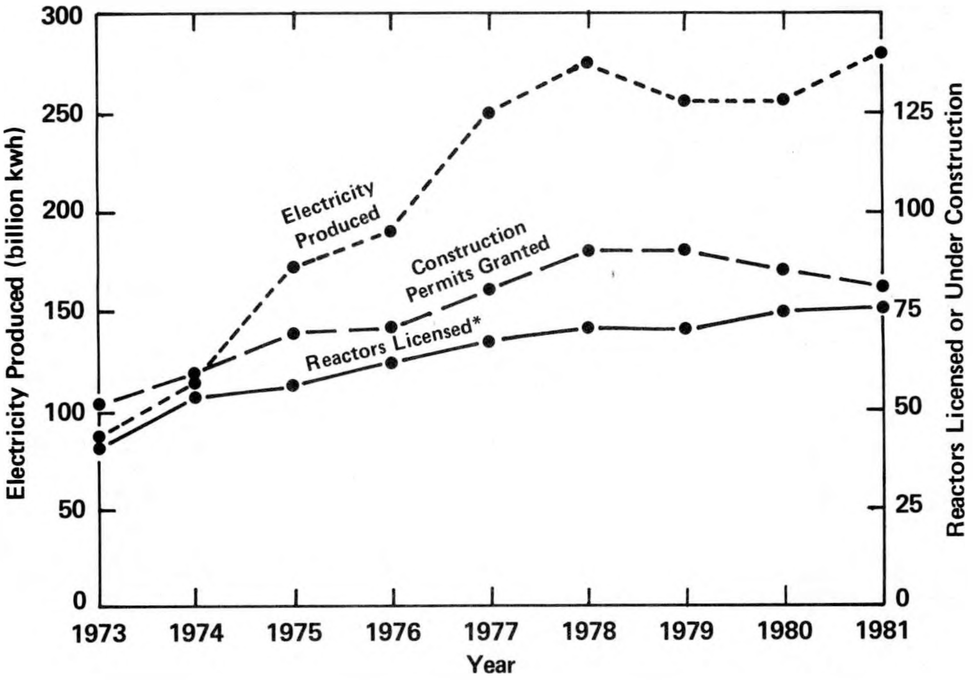
Nuclear-generated electricity grew from 4.5 percent (83 billion KWH) of all electricity generated in 1973 to a high of 12.5 percent (276 billion KWH) in 1976 and then declined slightly to about 11 percent (251 billion KWH) in 1980 when some reactors were closed down for reassessment and modification ordered by the Nuclear Regulatory Commission.[26] Total nuclear-generated electricity once again increased over the previous year in 1981. Figure 10 shows these trends. Despite a decline in the number of construction permits and a cessation of new orders since 1978,[27] commercial nuclear generating capacity is expected to more than double (from 55 to 130 GW) between 1980 and 1990,[28] primarily because reactors that are currently in various stages of construction will be completed during this period.[29]

Employment in the nuclear industry will be affected by both the increase in the number of reactors online during the 1980s and early 1990s and the level of federal funding for fission R&D. Current total employment in nuclear-related activities in selected occupational categories is presented in Table 1. By far the largest occupational groups are engineers (more than 40,000) and technicians (more than 45,000). As the reactors currently under construction are completed, the need for engineers, technicians, and other workers to operate and maintain them will intensify. For example, a recent survey of electric utilities involved in the generation of nuclear power showed that during the next ten years they will have a 10 percent increase in the number of engineering positions connected with their nuclear operations, a 130 percent increase in health physicist positions, a 40 percent increase in health physics technician positions, and a more than 70 percent increase in licensed operator postions.[30] At the same time, the number of B.S. graduates from nuclear-related engineering programs in universities and the number of graduate enrollments in those programs are both expected to decline. Enrollments in health physics programs are expected to remain constant, despite the increasing demand for these scientists.[31]

New incentives for graduate enrollments and for the maintenance of faculty size in nuclear and other engineering departments, health physics programs, and other nuclear-related disciplines may be needed in the 1980s if there is to be a sufficient professional manpower base to support the renewed growth of nuclear power in the 1990s. As indicated in a recent DOE report, B.S.-level nuclear engineering programs require about 10-15 years to establish "from scratch," and graduate programs may take even longer.[32]

Even without the construction of any additional reactors beyond those currently being built, however, nuclear and other engineers and scientists from several fields (e.g., chemistry, physics, and computer sciences) will be required. They will be needed to conduct research, to design systems to solve existing problems (including the storage and disposal of nuclear wastes and the redesign of reactor systems to improve safety) as well as to operate and maintain existing nuclear power plants. In addition, nonenergy nuclear activities, such as weapons development, will continue to employ a large number of related scientists and engineers.

Figure 10. Nuclear Generation of Electricity: Number of Reactors Licensed, Number of Construction Permits for Reactors Granted by the NRC, and Billion Kilowatt Hours of Electricity Commercially Produced, 1973-1981



* Includes two commercially operating, but not licensed, DOE reactors.

Source: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (February 1982).

TABLE 1. NUCLEAR EMPLOYMENT IN SELECTED OCCUPATIONAL GROUPS, 1981

Occupation	Nuclear-Related Employment*
Engineers	41,400
Nuclear engineers	5,300
Scientists	13,400
Health physics professionals	1,400
Technicians	45,900
Health physics technicians	4,300
Electrical and electronic technicians	8,200
Reactor operators	5,700
Senior licensed operators	1,400
Licensed operators	1,500
Unlicensed operators	2,800

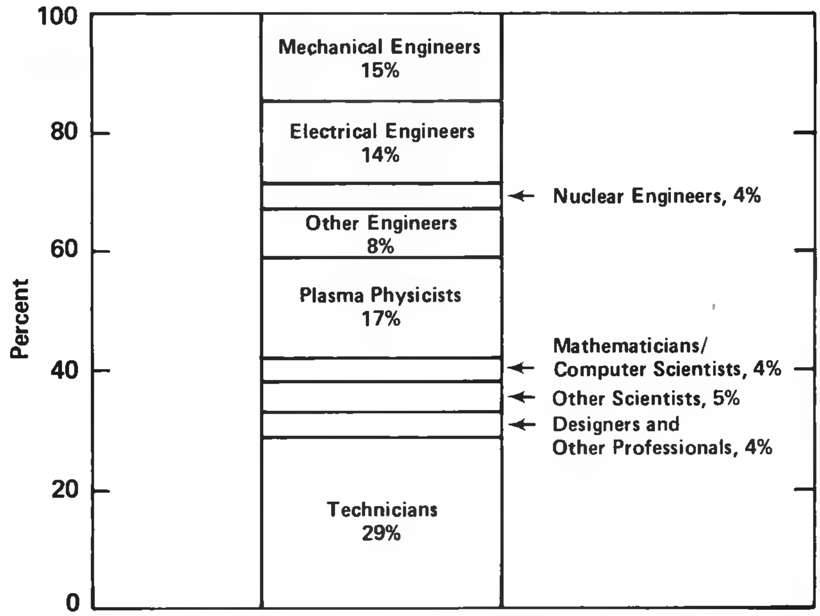
*Includes nuclear-related civilian employees of the U.S. Department of Energy and Nuclear Regulatory Commission, electric utilities, and firms in the private sector, including those at government-owned, contractor-operated facilities. Other federal employees (including members of the military), plus employees of state or local governments, medical institutions, uranium mining operations, construction contractors, and universities are excluded.

Sources: Oak Ridge Associated Universities, DOE, Form ERDA-601 "Survey of Nuclear-Related Establishments," 1981; Institute of Nuclear Power Operations Survey of Electric Utilities, 1981; and unpublished DOE and NRC information.

MAGNETIC FUSION ENERGY

The federal government has funded magnetic fusion research at universities, contractor-operated laboratories, and private firms for several years, and a specialized scientific, engineering, and technical workforce has developed. The current distribution of professional and technical employment in DOE-funded fusion research is presented in Figure 11. The majority of electrical and mechanical engineers are at the B.S. or M.S. level, while about one-half of the nuclear engineers and more than 90 percent of the plasma physicists are at the Ph.D. level.

Figure 11. Professional and Technical Employment Distribution in DOE-Funded Magnetic Fusion Energy Activities, 1981



Source: Oak Ridge Associated Universities, *Manpower Requirements and Supply for Magnetic Fusion Energy, 1981* (Oak Ridge, Tennessee: 1981).

In the Magnetic Fusion Energy Engineering Act of 1980, Congress established explicit goals through the end of the century for developing this technology. These goals include the construction of a test reactor and a demonstration reactor--the first in the middle 1980s and the second in the middle to late 1990s. If these goals are achieved, the number of scientists, engineers, and technicians involved in magnetic fusion R&D will increase significantly. Although total employment in this energy sector is very small compared with other energy sources, shortages in some of the critical fields may occur because of highly competitive demand in other energy sectors and in nonenergy industries. For example, job openings for computer scientists and for nuclear engineers may be difficult to fill with persons who majored in these same two fields. For this reason, the DOE Magnetic Fusion Energy Technology Fellowship program was established to attract engineering students of high quality to this area of specialization. Approximately 80 M.S. and Ph.D. degrees will be awarded in 1982 to students majoring in magnetic fusion energy at schools participating in the fellowship program. Moreover, employment increases in this energy sector may increase only moderately over the next several years, since the projected budget levels for 1981 and 1982 are not as high as those called for in the Magnetic Fusion Engineering Act of 1980. Thus, it is likely that there will be an adequate supply of engineers with training in this field.[33]

RENEWABLES

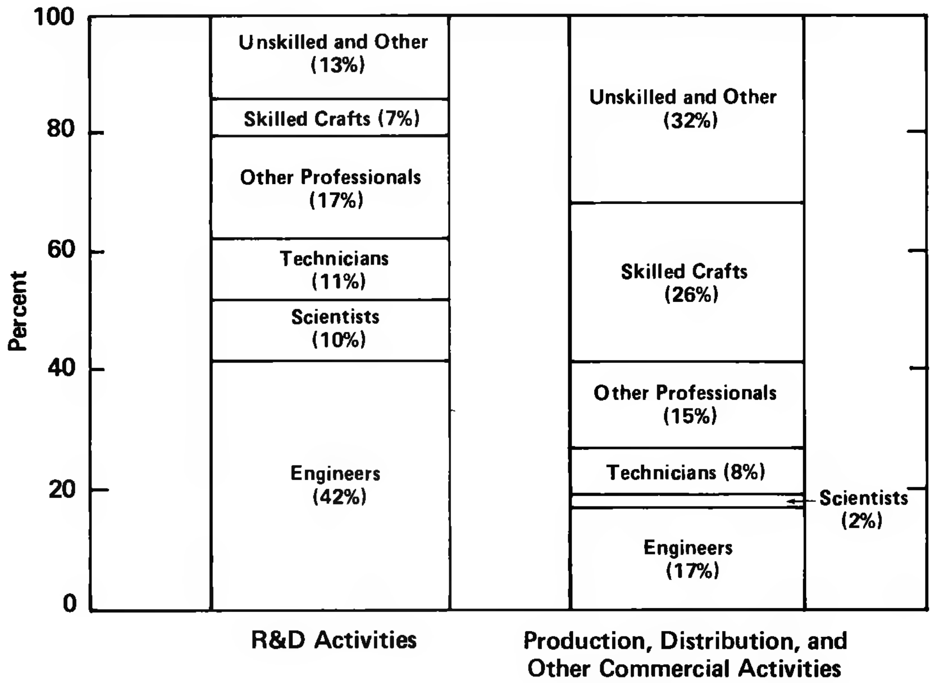
A wide variety of technologies and processes can be used to extract energy from solar and other renewable resources. The following are typically included among the renewable energy systems being used or under development:

Direct solar heating, cooling, and electric power generation;
Solar photovoltaic conversion;
Biomass combustion or conversion to liquid and gaseous fuels;
Wind power generation;
Hydroelectric power generation;
Ocean thermal conversion; and
Geothermal energy.

The employment impact resulting from these renewable technologies can be found in many activities--research and development, manufacturing, production, distribution, construction, installation, marketing, and other commercial endeavors.

The number of workers currently employed in some of the renewable energy technologies is very small. However, a late 1970s survey of manufacturers involved in solar energy activities suggests that in 1978 approximately 22,500 workers were employed in about 2000 separate firms.[34] As illustrated in Figure 12, the survey indicated that engineers comprised the largest occupational group among workers engaged in R&D activities. Together, scientists, engineers, and technicians accounted for nearly two-thirds of those engaged in solar energy research and development. Unskilled and skilled workers constituted the largest occupational categories of those involved in production, distribution, and other commercial activities. Another DOE-sponsored survey found that in 1977 there were approximately 3,300 person-years of geothermal-related employment in universities, government agencies, and private firms.[35] Similarly, an ORAU study for DOE estimated that the production of energy from the combustion of wood biomass accounted for the employment of roughly 50,000 workers in 1980.[36]

Figure 12. Employment Distribution in Solar Energy R&D and Production, Distribution, and Other Commercial Activities, 1978

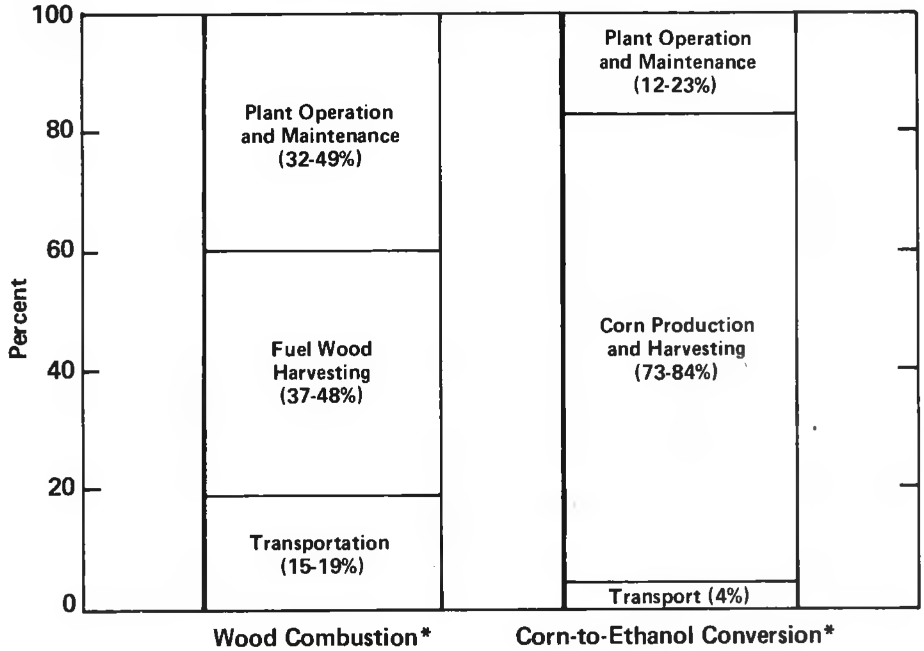


Source: U.S. Department of Energy, *Solar Energy Employment and Requirements 1978-1985* (Columbus, Ohio: 1980).

The federal government's role in renewable energy R&D is scheduled to decline during the first half of the 1980s. Unless private research and development efforts expand rapidly, it is likely that the employment in all renewable energy R&D activities will decline. Thus, while 14 percent of all Ph.D.'s and recent bachelor's and master's degree recipients involved in energy-related activities were working in renewable energy areas in the late 1970s,[37] this number is unlikely to hold in the 1980s.

Although future levels of energy production from renewable-energy resources are difficult to predict, biomass energy systems are expected to dominate growth in the foreseeable future.[38] The production of fuel-grade ethanol from agricultural crops and the direct combustion of wood are projected to make the greatest contributions. The construction, equipment manufacturing, and installation work associated with these activities will create temporary employment for some skilled workers, but the bulk of all employment supported by biomass energy activities will be for unskilled or semiskilled workers[39]--particularly unskilled farm workers and wood harvesters who might be needed to supply biomass resources to wood burning facilities or alcohol fuel conversion plants. On the other hand, there will be little employment of scientists and engineers in biomass-related energy production and use. The expected percentage distribution of employment by major type of activity is shown in Figure 13 for two major types of biomass energy systems: the direct combustion of wood from newly harvested wood chips and the conversion of corn to fuel-grade ethanol.

Figure 13. Expected Percentage Distribution of Employment by Type of Activity for Energy Extraction by the Direct Combustion of Wood and Corn-to-Ethanol Production, 1981



* Assumes all of the wood and corn used in these processes is supported by domestic production and harvesting. The production and harvesting percentages would be smaller if waste wood or diverted corn exports are used instead.

Source: Oak Ridge Associated Universities, *Some Employment and Earnings Implications of Regional Biomass Energy Utilization: New England and the Cornbelt States* (Oak Ridge, Tennessee: 1981).

Thus, while extraction of energy from all renewables has the potential to contribute an increasing share of the nation's energy, it is unlikely to create a substantially larger permanent demand for skilled, technical, and scientific workers needing specialized skills and training.

SECTION 2

REVIEW OF RECENT ENERGY-RELATED MANPOWER STUDIES

SECTION 2

REVIEW OF RECENT ENERGY-RELATED MANPOWER STUDIES

INTRODUCTION

The studies summarized and reviewed in this section address several important questions regarding energy-related manpower levels and needs. While two of the studies focus on the employment of scientists and engineers in all energy sectors, the others concentrate on some aspects of employment for a single energy source. The topics cover the supply, demand, and potential shortages of scientists, engineers, technicians, and (to a lesser extent) skilled laborers. The focus of the papers ranges from national to regional, and both current and future employment estimates are provided. Other topics covered include the employment needs for building a single coal synthetic fuels facility, training needs in critical occupations, and labor productivity.

The studies, as a group, are not all-encompassing: they do not cover every important question concerning the response of highly trained and skilled workers to market pressures for increased domestic energy production and energy conversion. Rather, they are a selection of some of the most important recent attempts to answer a variety of pressing questions in this area. No single model or common methodology is used in the studies. Various conceptual approaches and research designs have been developed and applied; and consequently, a mixture of substantive findings has been produced.

The reviews of the eleven energy-manpower studies follow a rather structured format. First, the major objectives of the study are discussed. Second, a brief description of the approach or method used to address the problem is provided. Third, the most important findings of the study are summarized and highlighted. Fourth, a few comments are offered on the timeliness of the study, the appropriateness of the assumptions on which the study was based, and the confidence with which the conclusions can be accepted.

SCIENTIST AND ENGINEER STUDIES

U.S. Department of Energy, Office of Energy Research, *Doctoral Scientists and Engineers Working in Energy-Related Activities, 1979*, prepared by R.B. Garey and S.E. Bell, Oak Ridge Associated Universities (Washington, D.C.: USDOE, 1982).

Objective

This report examines the fields and types of employment of a sample of doctoral scientists and engineers who described their professional activities as being predominantly energy-related in a 1979 survey. Additionally, the study attempts to relate some of the trends in energy-related Ph.D. employment between 1975 and 1979 to changes in energy policies and in the nation's energy development efforts. Specifically, the study focuses on the relationship between development of the various domestic energy sources and Ph.D. employment, mobility among doctoral-degree and employment fields, sector of employment, and the types of energy research or production activities in which doctoral scientists and engineers are engaged.

Approach

The authors obtained information on energy policies and energy trends from a wide range of published sources. Energy R&D expenditure information was obtained from National Science Foundation reports and from the *Congressional Quarterly Almanac*. Energy development activity and trends and their relationship to science and engineering Ph.D. employment were obtained from reports by several government agencies, by industry, by professional associations, and by other researchers.

The study also uses the results of a survey of a 7 percent sample of doctoral scientists and engineers in the United States, conducted biennially by the National Academy of Sciences--National Research Council (NAS-NRC) with the support of the U.S. Department of Energy, the National Science Foundation, the National Endowment for the Humanities, and the National Institutes of Health. The results of the 1979 survey are compared with the results of the 1975 and 1977 surveys to determine trends in energy-related Ph.D. employment.

Results

The number of doctoral scientists and engineers whose work was energy-related nearly doubled between 1975 and 1979: from 21,000 to 39,000 (12 percent of all Ph.D.'s). This growth paralleled large increases in funding for energy R&D, both from the federal government and from private industry (with company funds), as Figure 14 indicates. More than one-fourth of the Ph.D.'s identified petroleum or natural gas as the energy source on which they spent the most professional time, as Figure 15 shows.

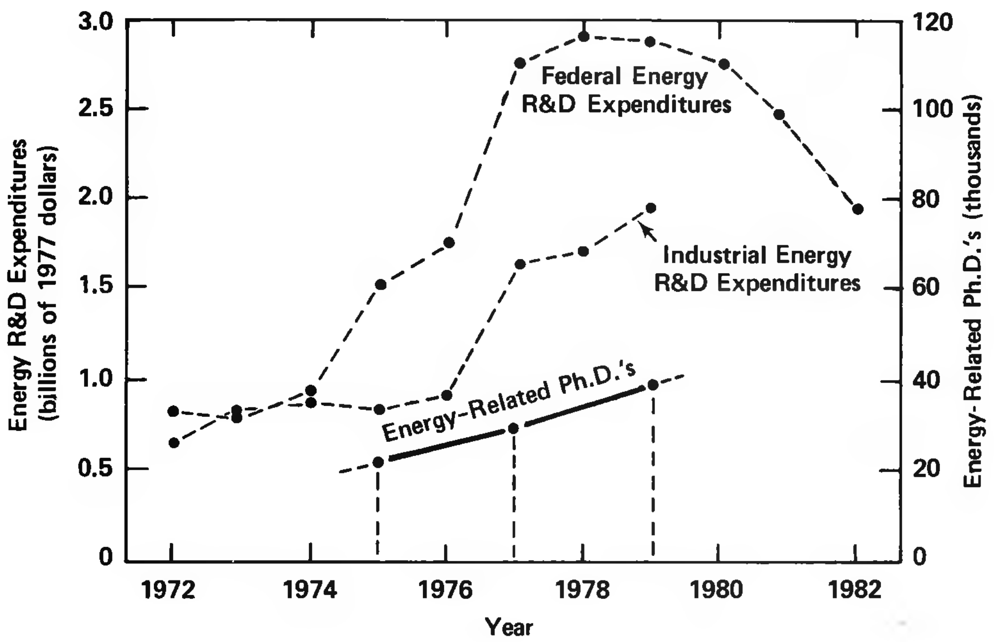
Ph.D.'s employed in occupations most in demand by various energy sectors increased substantially in the late 1970s. These include Ph.D.'s needed in the petroleum industry (e.g., chemical and petroleum engineering, geophysics, and chemistry), by the nuclear industry (nuclear and materials engineering, plasma physics, physical chemistry, and computer sciences), by the coal industry (chemistry and chemical, mechanical, and petroleum/fuel technology engineering), and for renewable energy research (engineering, physics, and chemistry). However, because of the sharp reductions in federal R&D funding between 1980 and 1982, the number of Ph.D.'s engaged in coal and in renewable energy industry research may decline in the future, unless private sector R&D funding increases. Proposed federal funding for nuclear energy R&D in 1983 is also below 1982 levels after an increase from 1981 to 1982. Graduate enrollments and Ph.D.'s awarded in nuclear engineering have decreased since 1979, suggesting that fewer doctoral researchers may be available in this field in the near future.

Almost all of the employment growth for energy-related Ph.D.'s between 1975 and 1979 occurred in the business/industry and education sectors, and almost none in the government or nonprofit sectors. There was a substantial increase (from 4,000 to 9,000) in the number of university-employed Ph.D.'s involved in energy research or teaching energy courses.

Comments

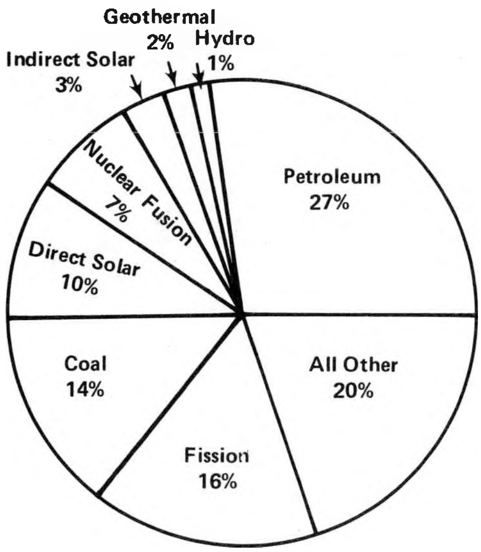
One of the most significant preliminary findings presented in this report is the apparent positive relationship between the level of federal R&D expenditures and the number of Ph.D.'s concentrating on a given energy source. However, this relationship has not yet been sufficiently empirically tested to predict whether the decline in federal budget authority for R&D that has occurred in most energy sectors since 1979 will result in a leveling off of the late 1970s growth in the number of energy-related Ph.D.'s.

.Figure 14. U.S. Government and Industry Expenditures (in 1977 Dollars) for Energy Research and Development, 1972-1980; Federal Budget Estimates, 1981-1982; and Doctoral Scientists and Engineers Working in Energy-Related Activities, 1975, 1977, and 1979



Source: National Science Foundation and U.S. Department of Energy, Office of Energy Research.

Figure 15. Energy Source to Which Energy-Related Doctoral Scientists and Engineers Devoted the Most Time in 1979



Source: U.S. Department of Energy, Office of Energy Research.

There were slight changes in the wording of some of the questions on the survey between 1975 and 1979 making it easier in the 1979 survey for teachers to identify themselves as working in energy-related activities. Therefore, some of the changes observed over the four years in the number of Ph.D.'s teaching in universities and increases in the number identifying themselves as energy-related may be attributable to the questionnaire differences rather than true employment trends.

PETROLEUM AND NATURAL GAS

National Petroleum Council, *Materials and Manpower Requirements for U.S. Oil and Gas Exploration and Production--1979-1980*, (Washington, D.C.: National Petroleum Council, 1979).

Objective

As an advisory committee to the Secretary of Energy, the National Petroleum Council provides information to the government on the current and future status of the oil and gas extraction industry. In 1978, the Secretary requested a study of materials and manpower requirements for exploration and development in the oil and gas industry that would examine needs both for the period 1979-1981 and for the longer term. Specifically, the study was supposed to identify any materials or personnel requirements critical to the growth of the industry that might be in short supply over the next several years.

Approach

The National Petroleum Council prepared 34 different questionnaires and mailed one or more to each of more than one thousand exploration and production firms; associated manufacturing, supply, and service firms; banks; professional associations; and universities. The purpose of the surveys was to obtain data from which to make projections of: (1) high and low levels of drilling activity that might be expected in the 1980s; (2) the capability of manufacturing, supply, and service industries to support growth in the industry; and (3) "the extent to which industry levels might be constrained by the availability of materials or manpower."

The surveys collected information on, among other things, the expected number of graduates (by degree level) in the crucial occupational fields. By comparing these supply estimates with the demand for graduates in these fields at the maximum expected drilling levels, the Council was able to identify any potential shortages of professionals.

Results

Overall, the study finds no areas of materials or manpower requirements that are likely to constrain the growth of the industry in the 1980s. The Council identifies geophysics, geology, and petroleum engineering as the crucial professional disciplines for exploration and drilling activities. Although there was a temporary shortage of advanced-degree graduates in these fields at the end of the 1970s, the Council expects an end to the shortage by the early 1980s. In petroleum geology, for example, there was a dramatic increase in university enrollments beginning in the late 1970s in response to growing industry demand. Consequently, an increasing number of geologists will be produced by universities at least through 1985, as Figure 16 indicates. At the same time, the demand for additional petroleum geologists to fill attrition vacancies and meet industry expansion needs will decline through 1985, Figure 16 also indicates. As a result, the total supply of petroleum geologists, at all degree levels, will be sufficient to meet total demand. By 1982, new advanced-degree graduates alone will be adequate to fill all openings for geologists.

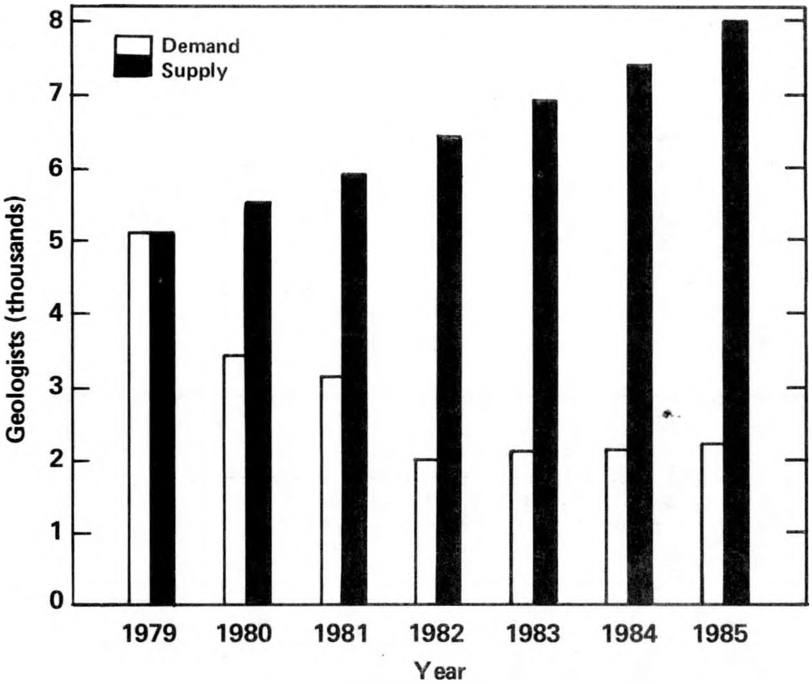
The Council also finds little reason for concern regarding the supply of engineers and geophysicists. Although there was a shortage of petroleum engineers in 1979, oil and gas companies were able to hire graduates from related disciplines to fill their needs. Moreover, by 1980 and 1981, the Council predicted an excess of petroleum engineering graduates, as Figure 17 shows. Similarly, the report predicts there will be no shortage of persons to fill geophysicist positions because 70 percent of the scientists currently working in this field hold degrees in physics, computer sciences, engineering, or some other related discipline.

Much less analysis of the outlook for technicians and skilled workers is offered, but the Council finds no reason to expect severe shortages of the operators, mechanics, technicians, and field supervisors necessary to place and maintain drilling rigs. The industry apparently did attract the necessary personnel during the heavy growth period of 1973-1979, and the Council expects slower industry growth in the 1980s. Although undesirable working conditions reportedly result in a high turnover rate for these occupations, companies report increased recruitment and training efforts to compensate.

Comments

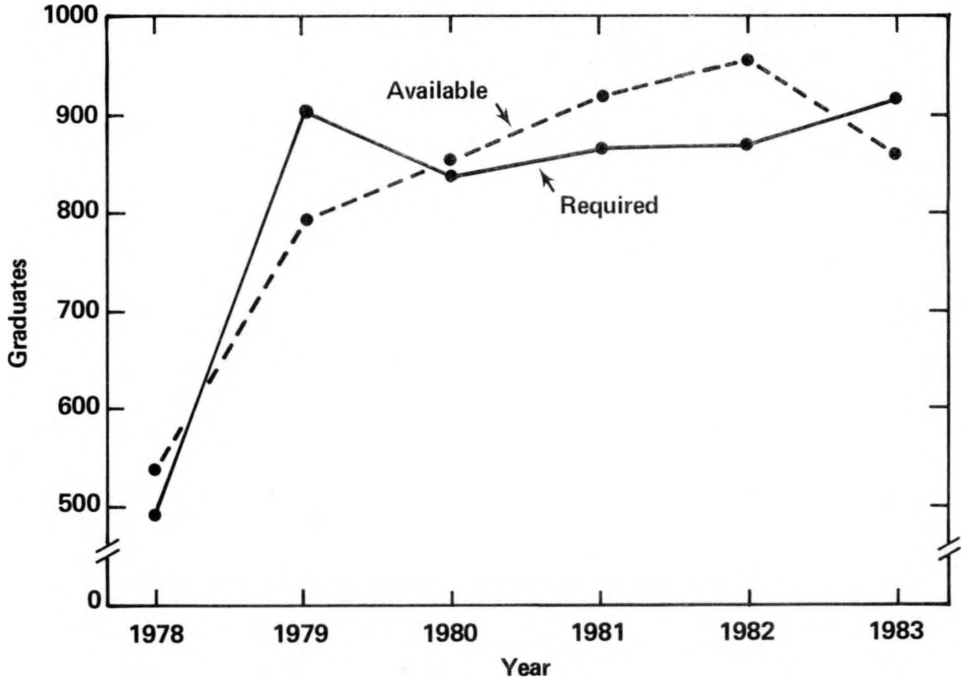
This study, which the Council recommended updating in the early 1980s, was conducted during 1978 and 1979, and thus its projections do not take into account the positive effects on industry activity of rapid increases in world oil prices and the accelerated decontrol of domestic prices that occurred in 1980 and 1981. For example, the Council's projections of the number of wells drilled per year was very

Figure 16. Estimated Supply versus Estimated Demand for Petroleum Geologists, All Degree Levels, by Oil and Gas Companies



Source: National Petroleum Council, *Materials and Manpower Requirements for U.S. Oil and Gas Exploration and Production--1979-1980* (Washington, D.C.: 1979).

Figure 17. B.S./M.S. Petroleum Engineering Graduates Available and Required in U.S. Industry, 1978 and Projected 1979-1983



Source: National Petroleum Council, *Materials and Manpower Requirements for U.S. Oil and Gas Exploration and Production--1979-1980* (Washington, D.C.: 1979).

close to the actual number drilled in 1978 and 1979, but was much lower than the actual number in 1980 and the preliminary estimates for 1981. Since the Council's projections of industry activity in the early 1980s are low, some of their manpower projections may need modification. For example, a lower percentage of the geologist and petroleum engineer openings may be filled by advanced-degree holders, and a higher percentage by B.S. degree holders. Also, a higher percentage than projected of the openings for geophysicists, petroleum engineers, and others may be filled by scientists and engineers from outside these fields.*

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*Compare: National Petroleum Council, *Materials and Manpower Requirements for Oil and Gas Exploration and Production--1979-1990* (Washington, D.C.: National Petroleum Council, 1979), p. J-7; and U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (March 1982):54,55. Also see American Petroleum Institute, "The Response of Drilling Activity to Higher Oil Prices," *Discussion Paper #024* (July 16, 1981).

COAL

J. I. Rosenberg, M. S. Mendis, D. M. Medville, B. A. Stokes, J. D. Reierson, and P. L. Cumiskey, *Manpower for the Coal Mining Industry: An Assessment of Adequacy through the Year 2000*, 2 vols, prepared for the U.S. Department of Energy, (McLean, Va.: The MITRE Corporation, 1980).

Objective

This study examines several of the important factors that will affect the quantity, quality, and productivity of the coal mining workforce through the end of the century. Its objectives are threefold: (1) to project the adequacy of manpower available for the industry to produce various levels of coal output; (2) to determine the effects of several forces and conditions (labor productivity, technology, wage changes, etc.) on the supply of and demand for labor; and (3) to gauge the adequacy of government education and training programs supporting the industry.

Approach

To accomplish the study's objectives, the researchers developed a system dynamics/econometric model to test the relationships between important variables expected to influence supply and demand. The development of the model required first an analysis of expected changes in coal technology (which affects occupational structure and labor demand). Data for the model were taken from published and unpublished documents of producers, industry organizations, unions, and government agencies and from several interviews.

The results are reported for three levels of growth in coal output through the year 2000 (4.0 percent per year--low growth case; 5.4 percent--most probable growth case; and 6.2 percent--high growth). These output growth rates were translated by the model into employment demand estimates by region and occupation, adjusting for various assumptions about key variables (labor productivity, underground/surface split in output, etc.). Similarly, labor supply estimates were produced based on assumptions about wage rates, federal scholarship funds, and other variables. Finally, nine analyses of the sensitivity of the supply and demand forecasts to changes in critical variables were also conducted.

Results

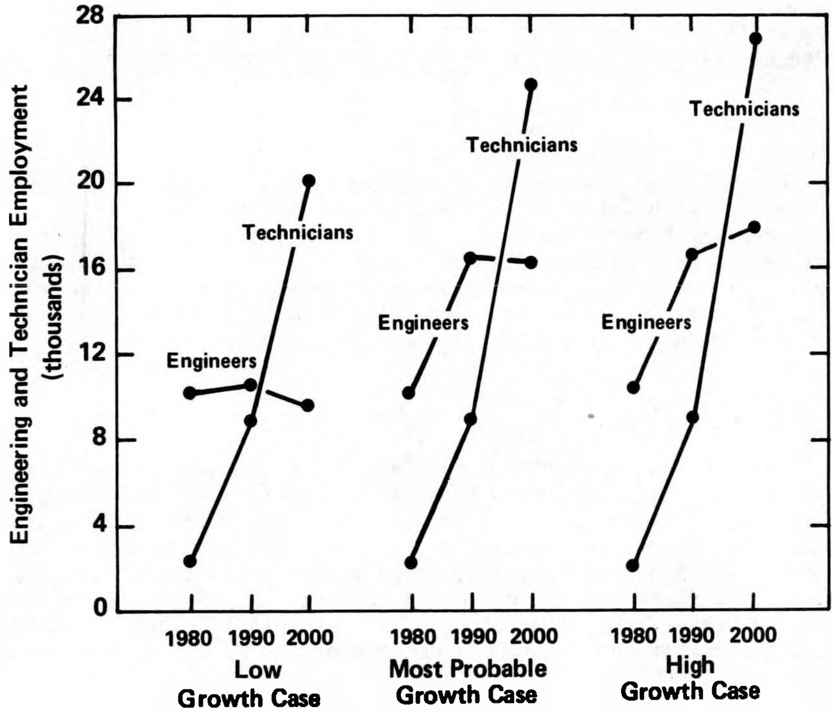
The findings indicate that while the supply of production workers will be sufficient under most future demand conditions, periodic shortages of experienced miners can be expected. These shortages are most likely to occur in two regions--the Northern Great Plains and the Midwest--because the demand for miners will grow much faster there than in other regions.

The supply of mining engineers should be sufficient under all but the highest coal demand scenarios. However, the number of mining engineering faculty members has declined substantially since the mid-1970s, and could inhibit the ability of universities to produce sufficient numbers of graduates in the near term. The numbers of mining technicians (usually with two-year degrees) employed in the industry will increase by a factor of ten or more between 1980 and 2000, as Figure 18 shows. This increase is much larger than the growth expected in any other skill category (engineer, scientist, miner, or administrator). Other findings of the study are that surface mining will grow dramatically relative to underground mining; labor productivity will increase in the 1980s; and coal production companies will support mining technology programs at two-year colleges to ensure that a sufficient number of technicians are produced.

Comments

The MITRE report intended to allow for the periodic updating of the projections provided in the study, by adjusting the model for changes in technology, public policy, and market conditions. However, the model is extremely complex and is perhaps too detailed, given available data, for estimating many of the projections. Another caveat *to the study's projections concerns the compounding of errors. Because the model arrives at employment projections through an iterative process, with each year's estimates based on the previous year's estimates, small errors can become big errors when projected several years into the future.*

Figure 18. Projected Employment of Technicians and Engineers in the Coal Mining Industry through the Year 2000, for Three Coal Output Growth Levels



Source: The MITRE Corporation, *Manpower for the Coal Mining Industry: An Assessment of Adequacy through the Year 2000*, 2 vols. (McLean, Virginia: 1980).

COAL

Electric Power Research Institute, *The Labor Outlook for the Bituminous Coal Mining Industry,* prepared by Harold Wool and J. B. Ostbo, The Conference Board (Palo Alto, California: Electric Power Research Institute, 1980).

U.S. Department of Energy, Office of Energy Research, *Occupational and Training Requirements for Expanded Coal Production,* prepared by Harold Wool, The Conference Board, (Washington, D.C.: USDOE, 1982).

Objective

These studies were undertaken to examine labor-related issues in the coal industry. The *Labor Outlook* study examines the degree to which coal output growth into the next century may be inhibited by the supply or cost of labor or by labor relations. Specifically, the authors focus on regional labor supply, demand, and cost in the coal mining industry. They provide detailed projections through 1990 and "'illustrative' projections of longer-term labor demand and supply factors." The *Training Requirements* study addresses more specific questions concerning training needs, training resources, and manpower data system improvements needed through the year 1995 in the coal industry.

Approach

The Electric Power Research Institute (EPRI) provided the estimates of future coal output levels for the *Labor Outlook* study. These projections were combined with productivity estimates derived from econometric models to give labor requirement forecasts for the industry. Labor requirements were, in turn, used to estimate the number of new entrants needed by the industry for employment growth and replacement. When compared with their estimates of labor supply, these demand projections indicate where and when any problems with availability of workers may occur. Labor-cost estimates were produced by combining projected wage rates and worker productivity levels. The data used in the models that produced these estimates came from published government and industry sources and from opinions and information obtained during interviews at 15 mining companies.

The *Training Requirements* study also provides occupational projections. Here, however, they are based on future coal output estimates from the Energy Information Administration (EIA) rather than from EPRI. The same methods and data as in the *Labor Outlook* study were used to convert the coal-output forecasts into new-entrant requirements and industry training needs. Because the EIA projections (1.47 billion tons in 1990) are higher than the EPRI projections (1.3 billion tons in 1990), the estimates of employment requirements in this report are also somewhat higher than those in the *Labor Outlook* report. The authors disaggregate the overall employment projections into occupations by using the proportions developed from the Occupational Employment Survey. From the results of the mail survey of mining companies, the authors compiled a list of company training programs that they then combined with information on vocational, government, and union training programs. By comparing these training resources with training needs, the authors assessed the adequacy of the training system.

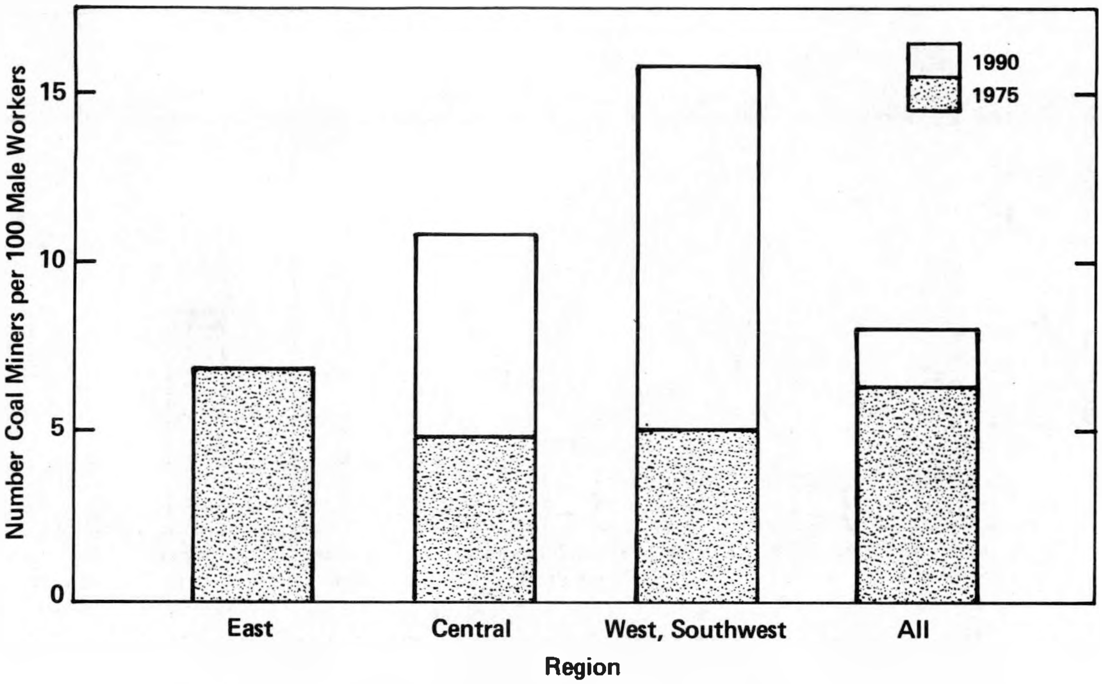
Results

The number of employed coal miners per 100 males in the labor force will increase dramatically in the Central and the West/Southwest regions of the country by 1990, as Figure 19 shows. However, the number of miners per 100 males will actually decline very slightly in the East, traditionally the center of heaviest concentration of coal mining. The coal miner percentage of the local labor force will expand the most in three subregions of the regions shown in Figure 19: the Midwest (part of the Central Region) and the Western Northern Great Plains and the Rockies (both part of the West/Southwest region). This rapid and large growth in these areas will be a product of the major shift away from underground mining to surface mining in the coming years. Only in these areas, and perhaps in the Central region, is there any potential for a shortage of miners through 1990.

Figure 20 contains estimates of labor costs, projected through 1990, from the *Labor Outlook* study. Unit labor costs per ton of coal produced will increase at a very modest rate, in real terms, primarily because productivity is projected to increase.

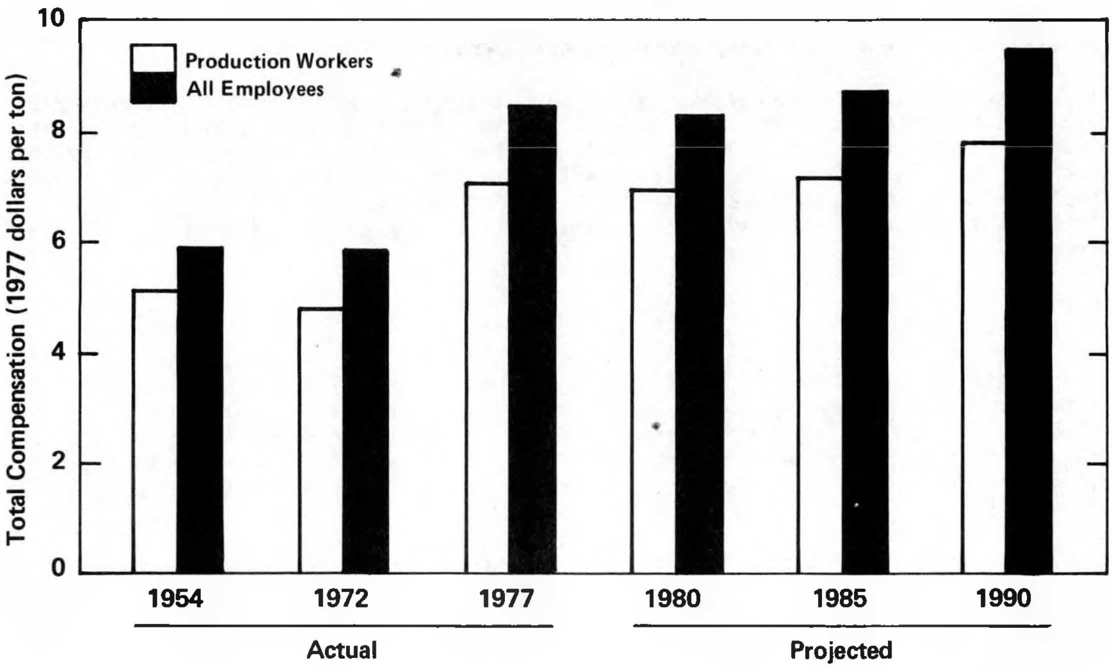
Because training requirements vary by occupation, an important component of the *Training Requirements* report is an occupational matrix that disaggregates industry employment into specific management, professional, and mining occupations for deep and surface mining. The major occupational categories in this matrix are summarized in Figure 21. A much more detailed table is provided in the report. As the figure indicates, the three largest categories of workers are equipment operators, mechanics/crafts, and laborers. The occupational patterns are different for surface and underground mines, however. Relatively few laborers, supervisors, and other production workers are found in underground mines, for example.

Figure 19. Number of Coal Miners per 100 Males in Labor Force by Region for 1975 and 1980



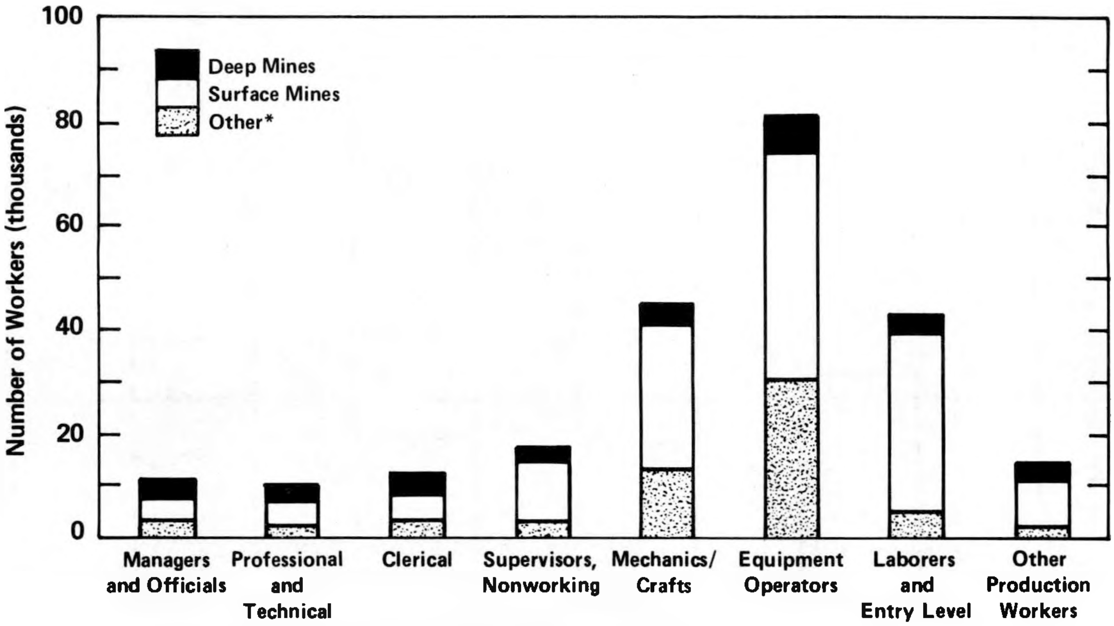
Sources: Electric Power Research Institute, *The Labor Outlook for the Bituminous Coal Mining Industry* (Palo Alto, California: 1980); and U.S. Department of Energy, Office of Energy Research, *Occupational and Training Requirements for Expanded Coal Production* (Washington, D.C.: 1982).

Figure 20. Unit Labor Costs in Bituminous Coal and Lignite Mining



Sources: Electric Power Research Institute, *The Labor Outlook for the Bituminous Coal Mining Industry* (Palo Alto, California: 1980); and U.S. Department of Energy, Office of Energy Research, *Occupational and Training Requirements for Expanded Coal Production* (Washington, D.C.: 1982).

Figure 21. Occupational Distribution of Employees in the Bituminous Coal and Lignite Mining Industry during 1977-1978



* Includes employees in separate mechanical cleaning plants, shops and yards, and coal company offices.

Sources: Electric Power Research Institute, *The Labor Outlook for the Bituminous Coal Mining Industry* (Palo Alto, California: 1980); and U.S. Department of Energy, Office of Energy Research, *Occupational and Training Requirements for Expanded Coal Production* (Washington, D.C.: 1982).

This report also includes projections of employment growth in each occupation through 1990. Total employment growth is expected to accelerate between 1985 and 1990, based on the EIA projections of coal output through the decade. Moreover, the occupational groups in which the greatest employment growth is projected are those that require significant amounts of training (managerial, professional, technical, supervisory, skilled maintenance, craft, and equipment operators).

Finally, the results of the survey of coal company training programs show that these firms provide extensive training to various categories of workers. Larger companies are somewhat more likely than smaller companies to provide training. The authors conclude that the training provided by coal companies, vocational schools, unions, and colleges will be adequate to meet training requirements in all regions except the west. Some increase in training programs may be needed in that region. Effective planning for training programs designed to meet future needs, however, requires a much improved coal manpower data system.

Comments

The projections of the future productivity of labor begin to fill a particularly important information need because productivity influences labor costs and, consequently, coal prices. Because, however, there is disagreement among researchers concerning two variables that the authors used to project productivity levels--forecasts of future coal output and the ratio of surface to deep mines in various regions of the country--some further research in this area would be helpful as a next step to verify or improve the projections.

As noted in the second Conference Board study (Occupational Training Requirements for Expanded Coal Production), *the projected labor requirements are based on 1980 estimates of future coal output by the Energy Information Administration, which some observers consider to be too optimistic. The study does provide perhaps the only survey of levels and types of training provided by coal companies.*

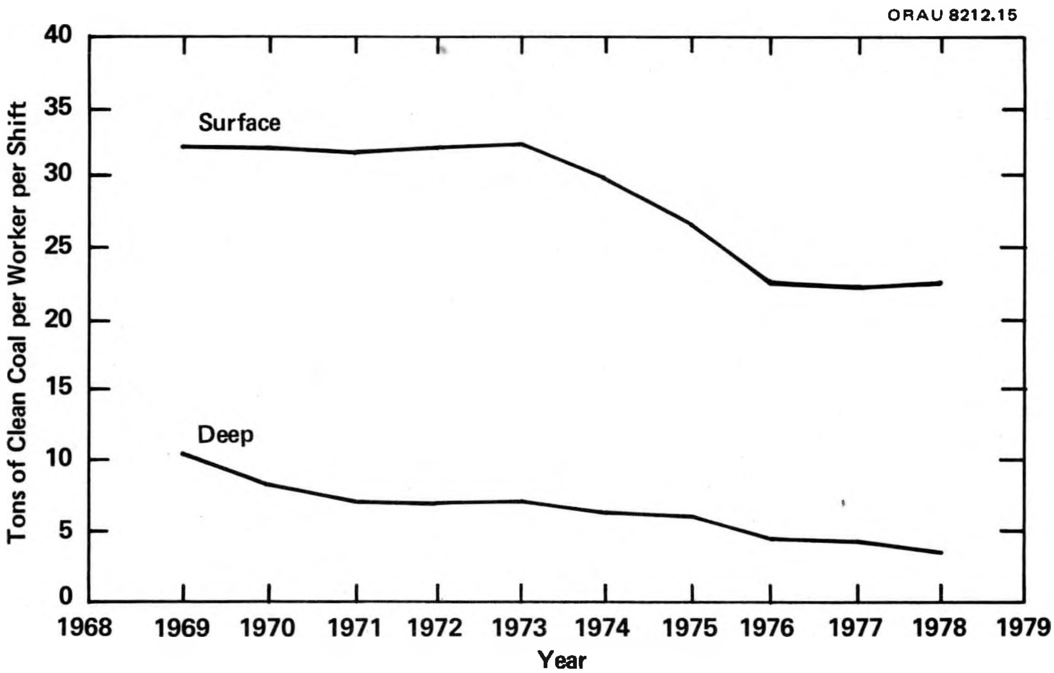
COAL

U.S. Department of Energy, Office of Education, Business, and Labor Affairs, *Determinants of Coal Mine Labor Productivity Change*, prepared by J. G. Baker and W. L. Stevenson, Oak Ridge Associated Universities, (Washington, D.C.: USGPO, 1979).

Objective

Coal mine labor productivity (tons per miner-shift) fell throughout the 1970s. Figure 22 details the historical trends in deep and surface mine labor productivity for the period 1969-1978. The decline in labor productivity since 1970 has increased the coal industry's demand for labor, cost of production, and injuries, and could hinder the ability of the industry to meet market demand. The purpose of this research study is to identify and measure the causes of labor productivity decline in surface and deep coal mines.

Figure 22. Deep and Surface Mine Labor Productivity, 1969-1977



Source: Department of Interior, Bureau of Mines, *Minerals Yearbook* (Washington, D.C.: various years).

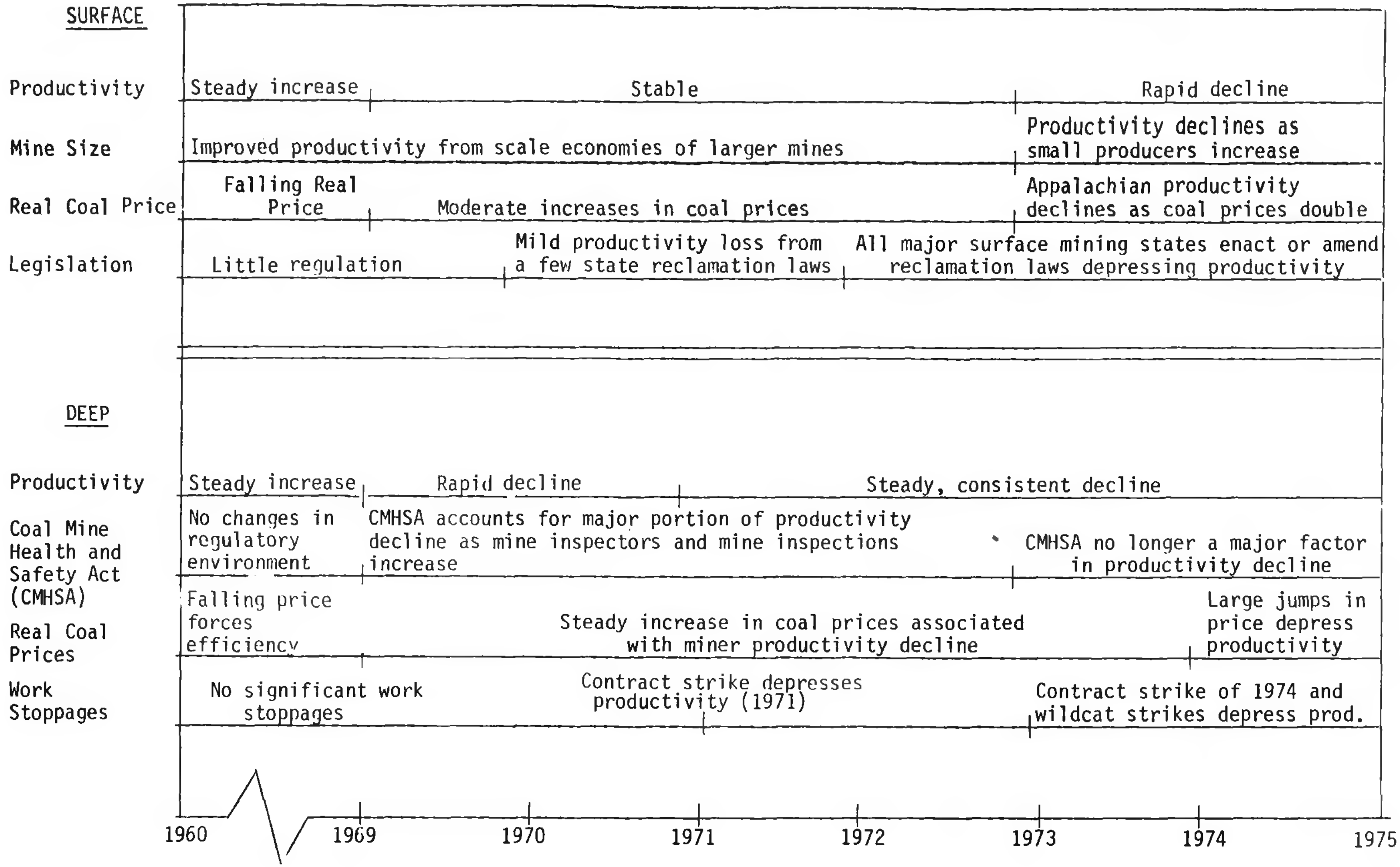
Approach

The report first reviews the important literature related to the topic and uses the results to develop a conceptual model to explain changes in coal mine labor productivity. The hypotheses developed from the model fit roughly into four general categories: geological causes (decreasingly favorable seams to mine as the industry expands), changes in the types of mining technology used, regulatory or institutional causes, and labor-related causes. The authors tested these hypotheses using econometric models applied to mine-level and state-level data sets for 1960-1977. The state-level data sets were obtained from several sources and publications from the Bureau of Mines, the Mine Enforcement and Safety Administration, the U.S. Department of Labor, and other federal agencies. The mine-level data sets covering Ohio, Illinois, and Kentucky were obtained from state government publications and from the Energy Information Administration's coal system data tape.

Results

The results, which are summarized in Figure 23, indicate that the majority of the labor productivity decline in deep mines was related to the Coal Mine Health and Safety Act (CMHSA) of 1969, work stoppages, and the increases in the demand for coal and subsequent coal prices. The CMHSA accounted for the

Figure 23. Major Causes of Productivity Change in Coal Mining, 1960-1975



Source: U.S. Department of Energy, Office of Education, Business, and Labor Affairs, *Determinants of Coal Mine Labor Productivity Change* (Washington, D.C.: 1979).

majority of the decline from 1970 through 1973. After 1973, the decline was partly a result of wildcat work stoppages and the 1974 general strike--probably because strikes disrupt the work process and because of the "demand surges" before and after strikes when utilities and manufacturers are trying to build up coal stocks. The decline in productivity since 1974 was also caused by rapid increases in coal prices, which may have enabled low productivity mines and mining techniques to be profitable and survive when otherwise they might have failed.

The major causes of decline in surface mining during the period were state reclamation laws passed in the early 1970s, rising coal prices (causing decline in Appalachia only), and the entry into the industry of many small mines. A major conclusion of the study is that part of the reason for the high productivity of the 1960s was that some of the costs of mining--worker injuries, black lung disability, and environmental damage--were not being paid for by the coal industry and coal consumers.

Comments

One potential cause of decreased productivity that is not tested in this study is labor turnover. Moreover, the relationship between coal prices and productivity is conceptually and methodologically difficult to measure, and more work needs to be done to test this relationship. Finally, the data sets analyzed in the study extend only to 1975 or 1976. Because productivity continued to decline in the late 1970s before it began to increase again at the end of the decade, further analysis of updated data sets to determine whether the findings remained valid in more recent years would be helpful.

COAL GASIFICATION PLANTS

U.S. Department of Energy, Office of Education, Business, and Labor Affairs, *Assessment of the Labor Impacts of the Commercialization of Coal Gasification Systems*, prepared by J. E. Lamson and T. D. Donakowski, Institute of Gas Technology (Washington, D.C.: USDOE, 1979).

Objectives

This study has two primary objectives: (1) to identify a high and a low estimate of the number of commercial coal gasification facilities likely to be built between 1980 and 2000; and (2) to estimate the number of construction workers, by craft, needed to build a single high-, medium-, or low-Btu coal gasification facility. In a second (later) phase of its analysis of coal gasification commercialization, the Institute of Gas Technology will use the results of this study to estimate the total national labor impact of constructing these facilities.

Approach

The report estimates the number of commercial coal gasification facilities likely to be built under high-level and low-level commercialization scenarios. These estimates were obtained from a 1978 American Gas Association projection and from an analysis of several published estimates of energy supply, demand, and prices by the year 2000. The two scenarios assume that the level of federal support for the industry would be substantial (high-level of commercialization) or negligible (low-level).

The number of workers needed to build a coal gasification facility is estimated by first disaggregating the project into separate construction activities (site development, electrical work, etc.). Then, each of these activities is compared with the parallel activity in building a chemical processing facility. For chemical processing facilities, Guthrie's 1974 *Process Plant Estimating, Evaluation and Control* guidebook indicates the number of construction workers needed, by craft, for each construction activity by giving a ratio of workers to dollar value of uninstalled equipment. These ratios for chemical processing plants are then applied to the equipment values for the various coal gasification construction activities. This method provides an estimate of the number of workers that would be needed in each craft to build: (1) a high-Btu facility that would produce 250 billion Btu of synthetic natural gas per day from 18,000 tons of coal and would require four years to build; (2) a medium-Btu facility producing 90 billion Btu of gas per day from 5,000 tons of coal and requiring two years to build; and (3) a low-Btu facility producing 95 billion Btu per day from 5,000 tons of coal and requiring two years to build.

Results

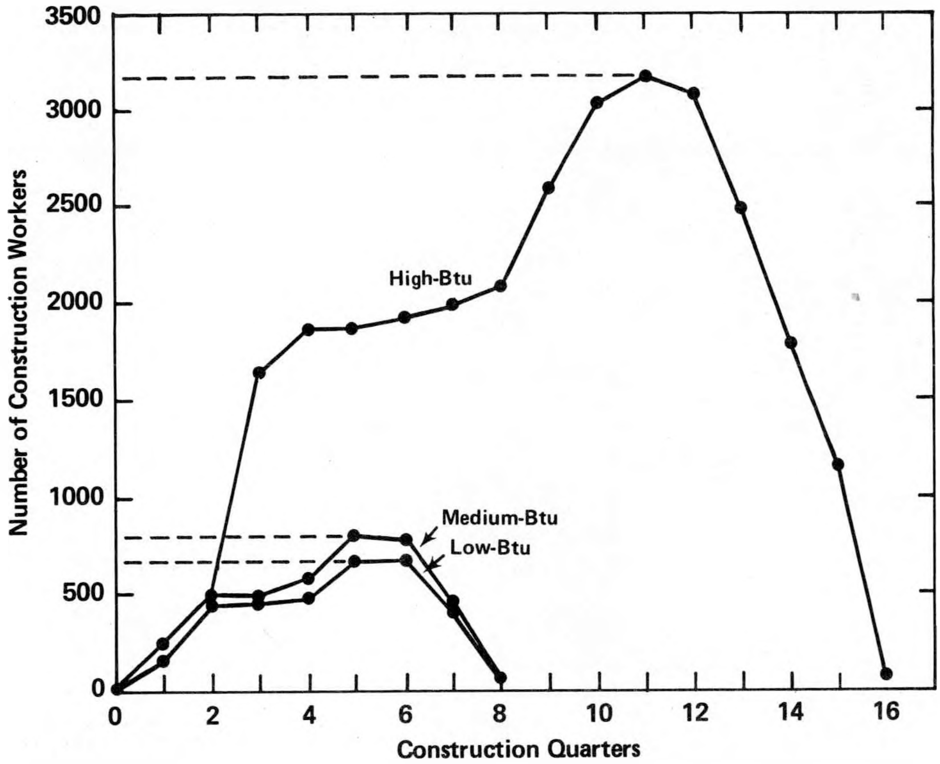
The study used a high commercialization scenario prepared by the American Gas Association's projection that 44 coal gasification facilities would be built by 2000. This level of commercialization could only be achieved, however, with strong federal government financial and regulatory support. If the federal government provides only limited support, which the authors contend is more likely, commercialization will approach their low-level scenario: 6 coal gasification facilities by the year 2000. The three most important potential constraints to commercialization appear to be: the availability of financing, the availability of suitable sites, and environmental restrictions (on strip mining and rural industrial development).

The level of employment required to build a single coal gasification facility depends upon whether high-, medium-, or low-Btu gas will be produced. The variation in construction employment levels needed for the three facilities is extremely large. The high-Btu gas facility, whose daily level of energy production would be almost triple that of the low- or medium-Btu facilities, would take twice as long to build and require eight times the construction worker-years. Peak construction employment would be more than 3,000 craft workers for the high-Btu facility, but much less than 1,000 workers for both the medium- and low-Btu facilities, as Figure 24 illustrates. Figure 25 provides a distribution of the major categories of craft employment needed to build the coal gasification facilities.

Comments

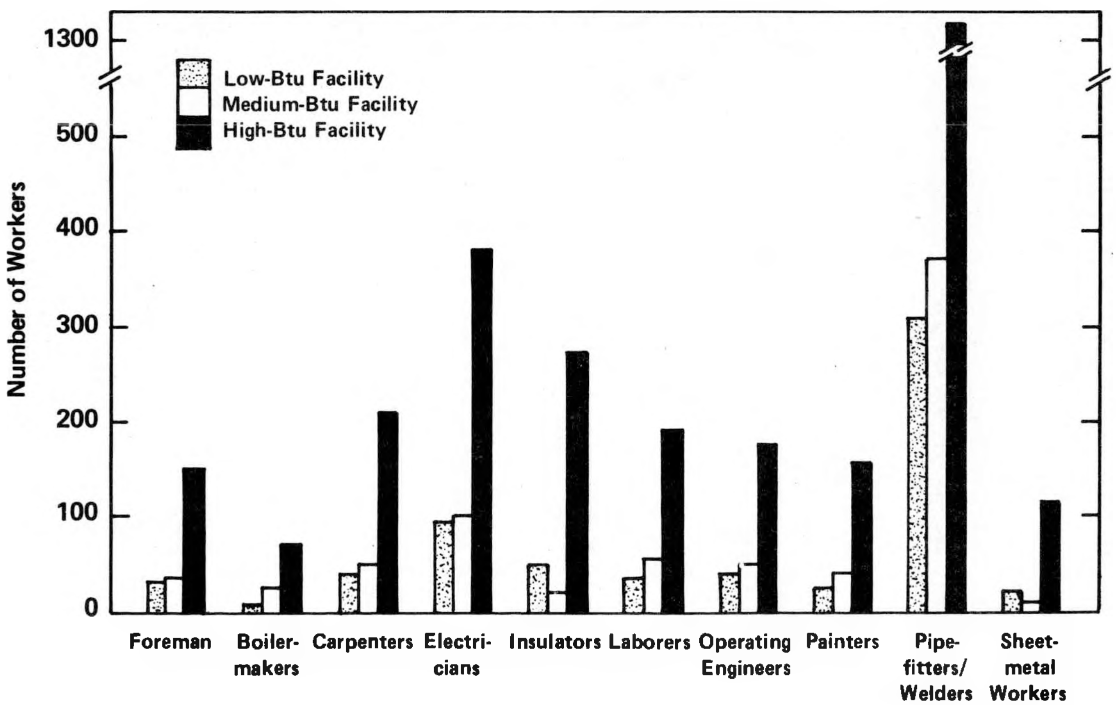
The high and low estimates of the number of commercial coal gasification facilities likely to be built by the year 2000 follow a well thought out analysis of the risk-taking behavior of finanacial institutions, constraints on facility siting, and the results of other commercialization studies. While the low commercialization estimate (6 facilities) seems plausible, the high estimate (44), which was originally predicted in 1978, now appears unlikely. The authors argue later in the report that 25-30 is probably the upper limit and that, given current trends and the lead time needed to build such facilities, even 25 may be unrealistically optimistic.

Figure 24. Construction Profiles for High-, Medium-, and Low-Btu Coal Gasification Facilities, by Quarter



Source: U.S. Department of Energy, Office of Education, Business, and Labor Affairs, *Assessment of the Labor Impacts of the Commercialization of Coal Gasification Systems* (Washington, D.C.: 1979).

Figure 25. Number of Workers Needed in Key Craft Categories during Quarter of Overall Peak Construction Employment, for Low-, Medium-, and High-Btu Facilities



Source: U.S. Department of Energy, Office of Education, Business, and Labor Affairs, *Assessment of the Labor Impacts of the Commercialization of Coal Gasification Systems* (Washington, D.C.: 1979).

By breaking the total construction project down into its component tasks, the authors are able to draw upon the empirically validated worker-to-equipment cost ratios used to estimate labor requirements for building chemical processing facilities. Their results are not policy-dependent, and this method *should be equally valid in predicting the employment directly associated with building such a facility in ten or twenty years.*

NUCLEAR FISSION

U.S. Department of Energy, Office of Energy Research, *A Study of the Adequacy of Personnel for the U.S. Nuclear Program,* prepared by J. F. Clarke (Washington, D.C.: USDOE, 1981).

Objective

Early in 1981, the Department of Energy's Office of Energy Research was asked to report on the adequacy of scientists, engineers, and other personnel in nuclear fields, and the manpower issues raised by the renewal of the federal program in support of nuclear power. The report addresses broad institutional issues as well as the status of nuclear education in the universities. For the purpose of formulating nuclear policy, the study develops recommendations for appropriate action on the educational problems identified.

Approach

The author relies mainly on information obtained during interviews with individuals in government, industry, and universities, as well as information from professional societies (such as the Health Physics Society), University Fusion Associates, and the University Nuclear Department Heads Organization. Because projections of future demand for nuclear personnel are subject to considerable uncertainty at this time, this study examines the historic patterns of nuclear development and the institutional infrastructure responsible for training nuclear personnel. The study then evaluates the ability of these institutions to respond to a variety of nuclear futures.

Results

In general, the author finds evidence of a current shortage of nuclear reactor operating personnel, which he attributes largely to the industry's recent shift from design and fabrication to operating completed reactors (Figure 26), complicated by increasing regulatory requirements. The supply of scientists and engineers in nuclear-specific disciplines (nuclear engineering, health physics, radiation biology) is of particular concern, since enrollments in these fields have remained stable or declined even though demand has been strong (Figure 27). This study finds that movement into nuclear engineering from closely related disciplines (mechanical and electrical engineering) is relatively easy, and the number of nuclear engineers required is small compared with the number of graduating electrical and mechanical engineers. As a result, the study concludes that the nuclear engineering shortage should be relatively short-lived, provided that the industry can continue to compete successfully for engineering graduates.

However, the report cites falling enrollments in nuclear engineering as evidence that it is difficult for the industry to compete successfully for new engineers. Moreover, because enrollments in health physics and radiobiology/ biophysics have been steady while demand for these specialists has increased suggests that this disadvantage is not restricted to engineering fields. Based on anecdotal evidence, the report concludes that this disadvantage results from negative public attitudes about nuclear power.

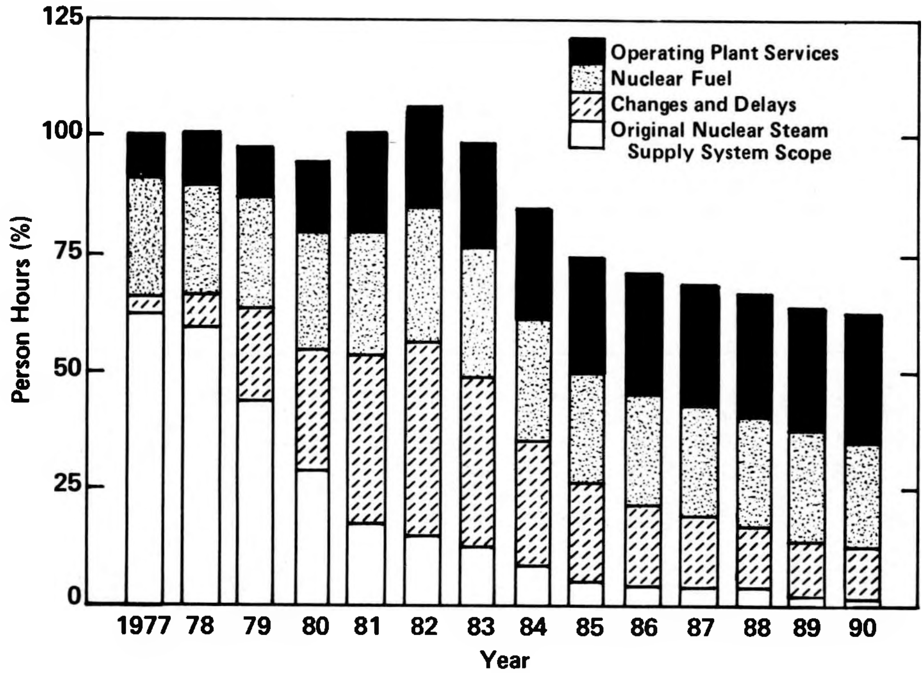
Limited enrollments not only contribute to current shortages, but jeopardize nuclear-related university programs. The report discusses what the loss of these programs might mean for the possibility of a "second nuclear era." New B.S. programs could probably be built "from scratch" in 10 to 15 years (the time required for the original nuclear education programs to reach peak production). Graduate programs would be more problematic. At least one report of a potential shortage in the late 1980s of advanced degree engineering graduates indicates that the loss of graduate-level programs could significantly delay future nuclear projects.

The author suggests that the federal government should take steps to improve the public image of nuclear power, which in turn would ease the current personnel shortage. For the longer term, the government should provide support for graduate programs in nuclear-related areas to preserve the capability for producing graduates that will be needed for a strong nuclear program.

Comments

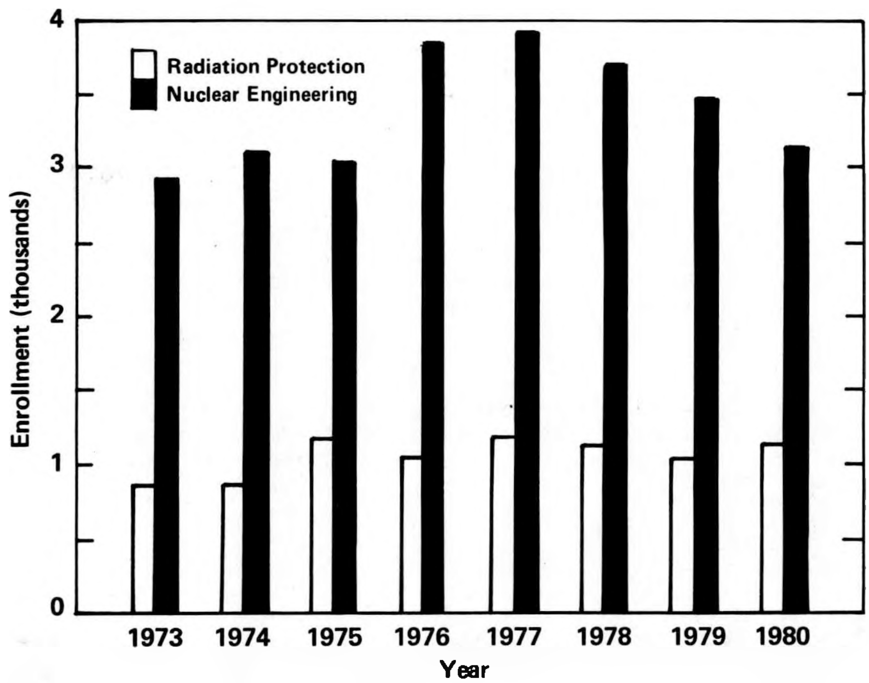
This study represents perhaps the only attempt to assess comprehensively the status of nuclear-related manpower. Rather than using the usual methods of projecting the supply of and demand for graduates in specific fields, the author analyzes the capability of the responsible institutions (universities, utilities, etc.) to adapt to changing conditions. However, because the author relies

Figure 26. Distribution of Engineering Effort (Person-Hours) in Steam Reactor Manufacture and Operation (with 1977=100 Percent)



Source: U.S. Department of Energy, Office of Energy Research, *A Study of the Adequacy of Personnel for the U.S. Nuclear Program* (Washington, D.C.: 1981).

Figure 27. Total Enrollment (3rd, 4th, 5th Year M.S., Ph.D.) in Nuclear Engineering and Radiation Protection. (Radiation Protection Includes Health Physics, Radiobiology or Biophysics, Medical Radiation Physics, and Health Physics Options in Engineering or Basic Science)



Source: U.S. Department of Energy, Office of Energy Research, *A Study of the Adequacy of Personnel for the U.S. Nuclear Program* (Washington, D.C.: 1981).

heavily on open-ended personal interviews for his data, much of the evidence on which the conclusions are based is anecdotal and indirect. Moreover, the meaning of some of the changes in health physics, radiobiology, or other enrollments in universities is somewhat ambiguous. It is not clear whether these changes represent long-term declines in enrollments or a stabilization after the rapid increases seen in the early 1970s.

MAGNETIC FUSION ENERGY

M. G. Finn, A. H. Hansen, and P. A. Harr, *Manpower Requirements and Supply for Magnetic Fusion Energy, 1981-2000*, prepared for U.S. Department of Energy, Office of Fusion Research (Oak Ridge, Tenn.: Oak Ridge Associated Universities, 1981).

Objective

This study was conducted to help the U.S. Department of Energy complete a task assigned by the Magnetic Fusion Energy Engineering Act of 1980. The Act sets ambitious goals for the development of fusion energy through the end of the century and directs DOE to "assess the adequacy of the projected United Stated supply of manpower in the engineering and scientific disciplines" that will be needed to achieve those goals. The Act also requires an appraisal of the adequacy of support for engineering and scientific education.

The study focuses on current employment and future manpower requirements for magnetic fusion energy to the year 2000. It also examines sources of labor for fusion energy in the disciplines most important to its future growth.

Approach

The DOE Office of Fusion Energy provided the authors with projections of the budgets for 1981-2000 needed to meet the objectives of the Act. These estimates are for both the total budget and several categories of activity. The authors use the results of a survey of establishments involved in fusion energy R&D and information about many of these establishments obtained from secondary sources to estimate the current fusion occupational distribution. They also project how this distribution will change within each of these categories of activity during the following twenty years and use this together with projected budgets to estimate total manpower requirements by occupation for 1981-2000. Supply is addressed by reviewing existing projections for the relevant occupations and by producing a new projection of graduates in engineering graduate programs oriented towards magnetic fusion.

Results

The budget (in 1981 dollars) and technical employment levels needed to meet the objectives of the Magnetic Fusion Energy Engineering Act are shown in Figure 28. The projected budgets will peak in the mid-1980s and mid-1990s because of the substantial capital expenditures associated with the construction of two large fusion devices. Employment growth will roughly follow (but be less pronounced than) budget growth through the end of the century.

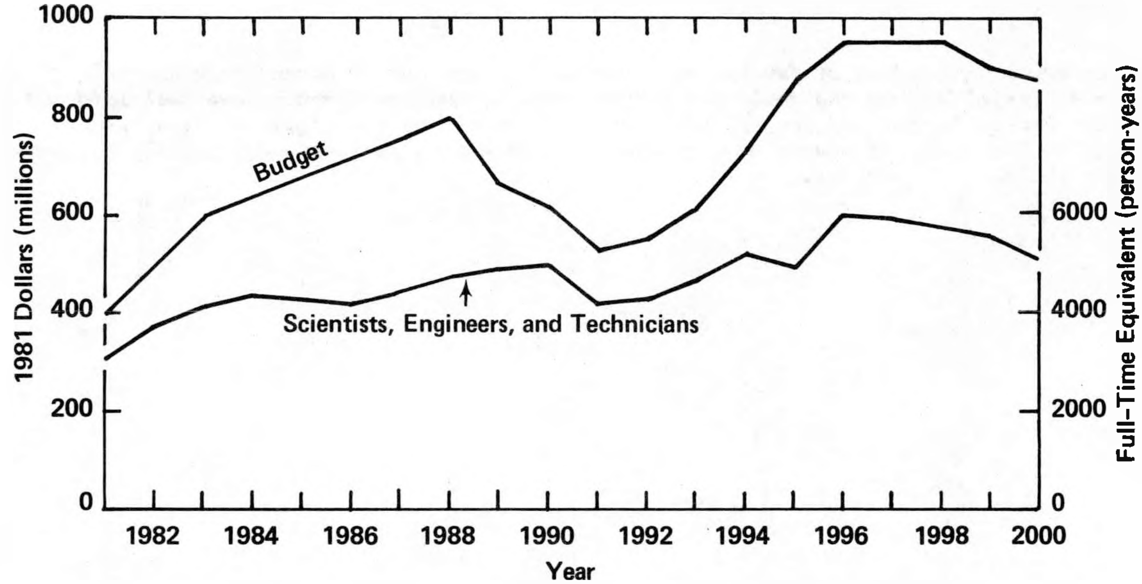
The mix of degree levels and occupations will change as the magnetic fusion program evolves; Ph.D. employment, for example, will not grow as fast as B.S./M.S. employment (see Figure 29). About 75 percent of all B.S./M.S. degree holders currently working in fusion energy are engineers, and this ratio will remain fairly constant throughout the projection period. The fastest-growing B.S./M.S. degree field will be mechanical engineering.

Plasma physics is and will continue to be the largest field at the Ph.D. level. However, as the fusion program focuses increasingly on the problems of designing and constructing a demonstration reactor, the proportion of Ph.D.'s whose degrees are in engineering will increase from 30 to 50 percent. Consequently, Ph.D. employment in several engineering fields, such as mechanical, materials science, electrical/electronic, and nuclear, will grow faster than plasma physics.

There are a considerable number of engineering schools with graduate programs in magnetic fusion technology. In the report, the authors examine projected future enrollment at 11 such schools that currently participate in a DOE-funded magnetic fusion energy technology fellowship program. The results indicate that, if recent funding for the fellowship program continues, and if current job opening trends continue, the number of degrees expected in fusion technology between 1982 and 1990 will nearly equal the projected engineering job openings during the the greatest growth in the fusion program.

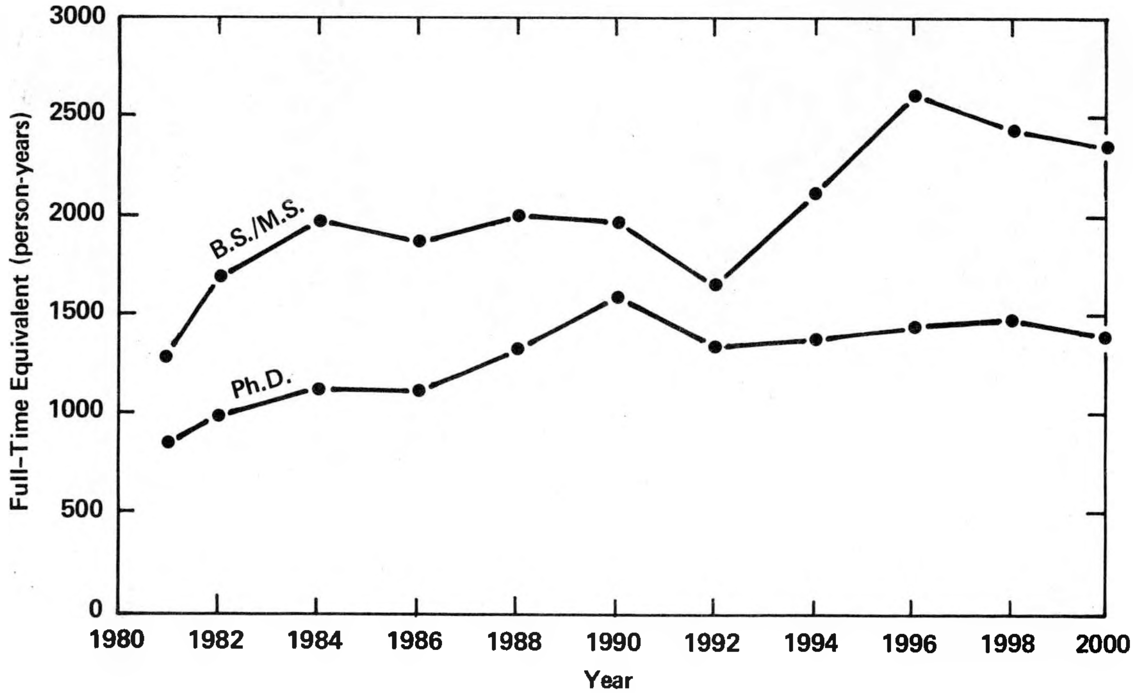
	Expected Degree Awards from Graduate Programs Participating in DOE Fellowship Programs	Projected Engineering Openings in the MFE Program
B.S./M.S.	586	692
Ph.D.	435	536

Figure 28. Projected Budget and Scientific, Engineering, and Technical Employment Levels for the Magnetic Fusion Energy Program for 1982-2000



Source: Oak Ridge Associated Universities, *Manpower Requirements and Sup*[illegible]*y for Magnetic Fusion Energy, 1981-2000* (Oak Ridge, Tennessee: 1981).

Figure 29. Projected Scientific and Engineering Employment Levels for the Magnetic Fusion Energy Program for 1981-2000



Source: Oak Ridge Associated Universities, *Manpower Requirements and Supply for Magnetic Fusion Energy, 1981-2000* (Oak Ridge, Tennessee: 1981).

These projections indicate a generally adequate supply of new graduates in magnetic fusion technology because some of the projected openings can be filled by persons without specialized training in fusion and because there will be additional graduates from other university programs.

Comments

Fairly accurate projections of funding requirements and employment demand were possible at the time the study was conducted because the goals for a high level of industry growth were well laid out in the Magnetic Fusion Energy Engineering Act of 1980. However, since the report was written, budget cuts have been proposed for 1983 that, if passed by Congress, will result in funding significantly below that needed to meet the goals of the Act.

RENEWABLE ENERGY SYSTEMS

U.S. Department of Energy, Office of Education, Business, and Labor Affairs and Office of Solar Applications, *Solar Energy Employment and Requirements, 1978-1985*, prepared by G. W. Levy and Jennifer Field, Battelle Columbus Laboratories (Washington, D.C.: USDOE, 1980).

Objective

The purpose of this study is to identify the types of employers in the solar industry, the occupations that will be crucial to development and expansion of the industry, and any industry-specific skills for which no formal training is available. The study offers a method for projecting industry employment in the future and provides estimates of employment levels for 1981 and 1983. The projections are for the combined employment in "all types of solar technologies and applications," including "space heating and cooling, water heating, industrial process heat, thermal power, ocean thermal conversion, photovoltaic conversion, wind conversion, and biomass conversion."

Approach

To assess the current and future employment impacts of solar energy technologies, Battelle Columbus Laboratories conducted a national survey of solar energy establishments in 1978. Respondents answered questions about total number of people employed, their occupational distribution, and the expected number of employees in 1981. Because the survey attempted to cover the entire range of solar activity, the questionnaire also asked for background information on the primary technology involved (space heating, cooling, photovoltaics, etc.) and the phase of activity (research and development, marketing, manufacturing, installation). A sample of the employees of responding firms was also surveyed to help determine training requirements for solar energy work, and to identify any new occupations that may have emerged.

Results

Based on survey responses, the authors estimate that 22,500 people worked for about 2,000 solar establishments in 1978. Engineers (especially mechanical engineers) formed the largest occupational group (Figure 30), in part because more than half of all solar workers (12,500) were engaged in research and devel-opment. Skilled workers dominated installation activities, while large numbers of both skilled and unskilled workers were employed in other commercial activities. No new occupations were identified in the solar industry. In the majority of cases, traditional training was cited as adequate preparation for solar work. However, about one-fourth of the employers identified additional skills that their work required, especially in solar design and installation. These skills can probably be incorporated into traditional training programs, and they do not substitute for more widely applicable skills.

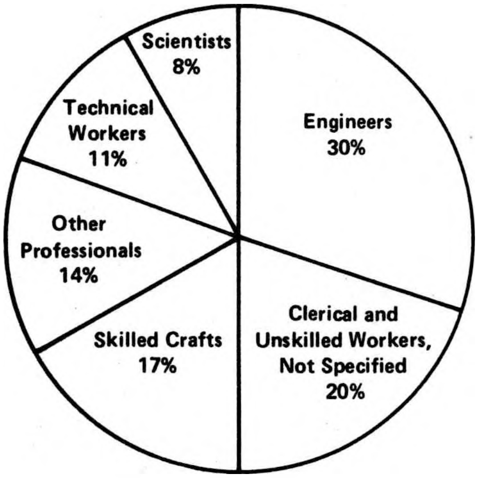
One of the more significant findings of the study is that firms enter and exit the solar area frequently--a sign of a young and still changing industry. Most of the responding firms were small, concentrated heavily on solar work, and were involved in space and water heating applications. Although a few large organizations had entered the field, they devoted only a small fraction of their workforce to solar activities.

Using these survey data, projected federal R&D funds, and a model of solar energy development and commercialization, the authors project solar employment levels to 1981 and 1983. Their results indicate large gains in solar employment between 1978 and 1983. These results can be traced in part to the assumption that the rapid increases in government-funded solar work under the previous administration will continue and that private funding of solar research and development will increase through 1983.

Comments

This report represents the most comprehensive effort to collect survey information on employment in solar industries in 1978 and provides an occupational profile that includes information on the skills and disciplines needed for various solar activities. Because the study found that solar industries were still growing and changing, these data may be most useful in comparison with later surveys of the same industries. The projections represent an early attempt to estimate employment growth in the industry, but are probably of less use now because of the lower solar R&D budget levels in the early 1980s and the extremely small sample of firms on which their commercialization model was based. Moreover, any change in the rate of commercialization in one or more solar technologies would affect the total projections.

Figure 30. Occupational Distribution in the Solar Energy Industry, 1978



Source: U.S. Department of Energy, Office of Education, Business, and Labor Affairs and Office of Solar Applications, *Solar Energy Employment and Requirements, 1978-1985* (Washington, D.C.: 1980).

RENEWABLE ENERGY SYSTEMS

U.S. Department of Energy, Office of Energy Research, *Geothermal Energy Employment and Requirements: 1977-1990*, prepared by R. L. Hannah and G. L. Magnum (Washington, D.C.: USDOE, 1982).

Objectives

The objectives of this study are to assess the employment status of the geothermal industry in the late 1970s, and to project its manpower needs through 1990. Specifically, the authors (1) estimate the total number of person-months of employment that scientists and engineers, technicians, skilled laborers, and others spent working in the geothermal industry and identify their activities and the type of organizations for which they worked at the time of the study (1977-1979); (2) identify occupations in which there are current or impending shortages of trained workers; (3) forecast employment levels and growth needed in the industry through 1990 if DOE's 1979 projections of industry expansion are to be achieved; and (4) estimate the likelihood of a sudden technological breakthrough that would greatly expand the use of this energy source.

Approach

To identify the population of government and private sector organizations that were at least peripherally involved in geothermal activities in the late 1970s, the authors mailed an initial survey questionnaire to a much larger list of organizations reputed to have some interest in geothermal energy. Each respondent was asked to supply some general employment information crosstabulated by geothermal activity. Organizations that replied that they were willing to participate further in the study either were selected for an in-depth personal interview or were mailed another survey questionnaire to obtain more detailed employment information. Finally, the likelihood of a sudden technological breakthrough in the geothermal industry by 1985 was estimated by a panel of "industry experts" using the Delphi method of analysis, and the results were used to adjust the authors' projections of future industry employment requirements.

Results

The survey and interview findings indicate that there were approximately 40,000 person months (3,300 person-years) of geothermal-related employment in 700 educational, public, and private organizations in 1977. This employment was, however, heavily concentrated in a few organizations. More than half of the person-months were in the 20 most active firms. Most responding firms devoted a very small portion of their time to geothermal activities.

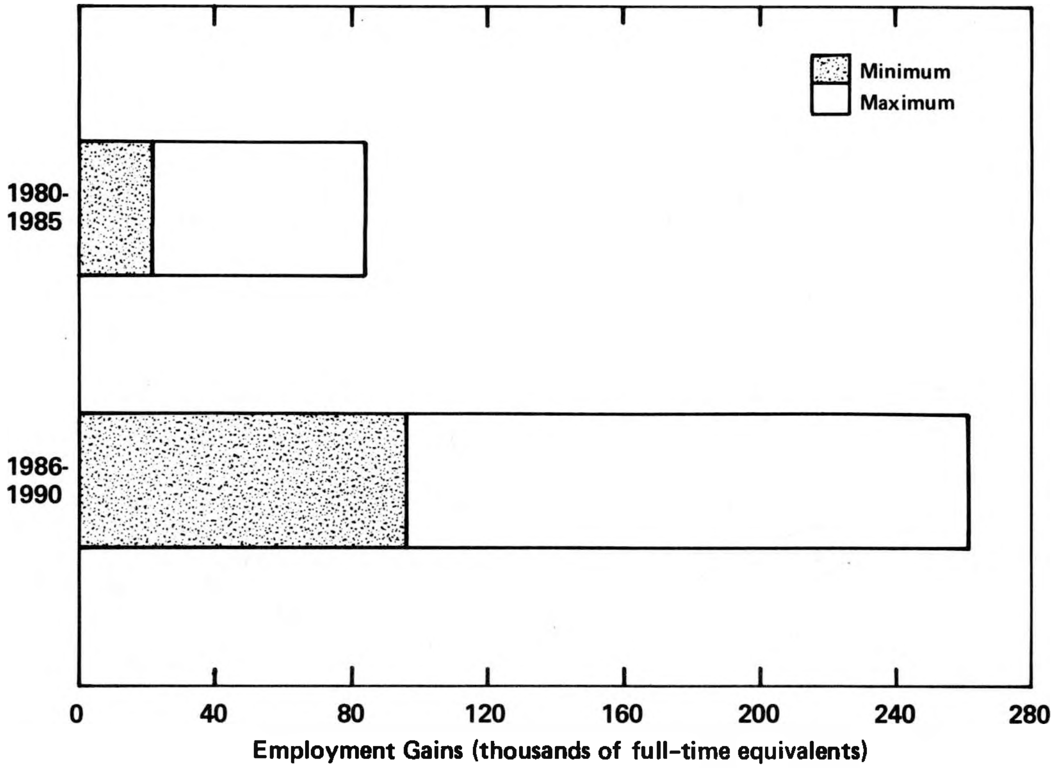
Scientists and engineers accounted for almost 60 percent of all geothermal employment. They were involved in a wide variety of geothermal activities, but were most heavily concentrated in the exploration and design phases. Approximately 18 percent of the person-months of employment were filled by technicians, and 6 percent by skilled workers. The activities in which workers at these levels of training were predominantly concentrated included well drilling, plant construction, and resource exploration.

The occupations for which employers most often mentioned problems in recruiting and retaining a sufficient workforce to allow the industry to expand were geology, geophysics, reservoir engineering, environmental engineering, and drill rigging. Workers in these fields were also being recruited heavily (and successfully) by the petroleum/natural gas industry, putting the geothermal industry at a comparative disadvantage.

Based on the DOE Interagency Geothermal Coordinating Council's projection of growth in geothermal production of electricity from 971 megawatts in 1980 to 9,315 megawatts in 1990 and proportionate growth in other geothermal uses (space heating, nonelectrical industrial applications, etc.), the authors forecast a large increase in person-years (full-time equivalents) of employment between 1980 and 1990. The bulk of this growth is supposed to occur in the second half of the decade, as Figure 31 below shows.

Finally, as a result of the Delphi analysis, the authors conclude that steady progress rather than a sudden technological breakthrough in the industry is to be expected. Consequently, an "unanticipated surge" in employment demand is unlikely.

Figure 31. Projected Employment Gains in the Geothermal Industry, 1980-1990



Source: U.S. Department of Energy, Office of Energy Research, *Geothermal Energy Employment and Requirements: 1977-1980* (Washington, D.C.: 1982).

Comments

The report indicates problem occupations identified by respondents, but the level or likely duration of shortages is not verified by independent data. The authors tie their employment forecast to the DOE Interagency Geothermal Coordinating Council's projection of geothermal energy production. These projections are that the number of megawatts of electricity produced annually from geothermal energy will increase by a factor of almost ten between 1980 and 1990. Because the federal geothermal R&D budget has been cut substantially since 1980, however, their projections of large increases in employment may be greatly overstated.

RENEWABLE ENERGY SYSTEMS

W. L. Stevenson, et al., *Some Employment and Earnings Implications of Regional Biomass Energy Utilization: New England and the Cornbelt States*, prepared for the U.S. Department of Energy, Office of Conservation and Renewable Energy (Oak Ridge, Tenn.: Oak Ridge Associated Universities, 1981).

J. R. Little and W. L. Stevneson, *Education and Training Implications of Biomass Energy System Use*, prepared for the U.S. Department of Energy, Office of Energy Research (Oak Ridge, Tenn.: Oak Ridge Associated Universities, 1981).

Objective

The principal objective of the companion reports is to assess employment and related impacts associated with the production of energy from trees, agricultural crops, and other biomass resources. Specifically, these studies project employment and training impacts for a wide variety of occupations involved in biomass resource harvesting, transportation, plant operations, general maintenance, administration, and marketing activities. These occupational groups include farmers, truck drivers, machine operators, managers, unskilled workers, and others. In the first of the above reports, special attention is given to two regions, New England and the Cornbelt, because of their respective supplies of wood and grain crops. Occupationally specific employment projections are offered for each region based on varying assumptions concerning biomass energy production. In the second report, national employment projections, which focus particularly on skill requirements, are provided. These projections are used to infer formal education and training needs that are, in turn, used to assess the adequacy of existing programs to meet the demand.

Approach

The employment-related information used for both reports came from observations of 189 specific biomass energy related activities. About 77 percent of the observations included personal interviews conducted during on site visits to operating facilities. The remainder consisted of telephone interviews and reviews of information in feasibility studies, environmental impact statements, or other reports on specific existing and planned facilities. These data provided the basis for an assessment of employment requirements for typical biomass energy facilities. From these, local, regional, and national employment and earnings impacts were estimated for various levels of biomass energy production.

Only the employment directly related to the production of biomass energy, and not the economy-wide employment impact, is considered in these reports. Moreover, the reports examine most closely the employment, education, training, and related implications of the biomass technologies that have the greatest commercialization potential and consider only those jobs or work activities closely related to one of the biomass technologies.

Results

Goals, forecasts, and estimates of potential biomass energy use vary considerably. In the near term, the direct combustion of wood and grain-to-ethanol conversion show the greatest promise for biomass energy utilization and employment. By the turn of the century, municipal solid waste, biomass gasification, and biomass-to-methanol conversion may make a significant contribution as well. All of these activities will produce employment. Future ethanol production is difficult to estimate, but employment levels associated with future production goals established by DOE are shown in Figure 32. If wood combustion were to generate 5 quads of energy by the year 2000 (a goal considered to be conservative by many), permanent employment in the wood energy industry alone would be in the range of 225,000 to 325,000 workers, as Figure 33 shows.

All biomass activities together may account for a significant number of permanent jobs at the national level. Not all would be net employment gains for the economy, however, because of some displacement of workers in other energy sectors. A fairly high proportion of the biomass jobs would be taken by unskilled workers in rural areas. Thus, a geographical and occupational as well as an industrial reallocation of labor will result from the substitution of biomass for conventional energy systems. These changing employment patterns are probably the most important employment implications of increased biomass use.

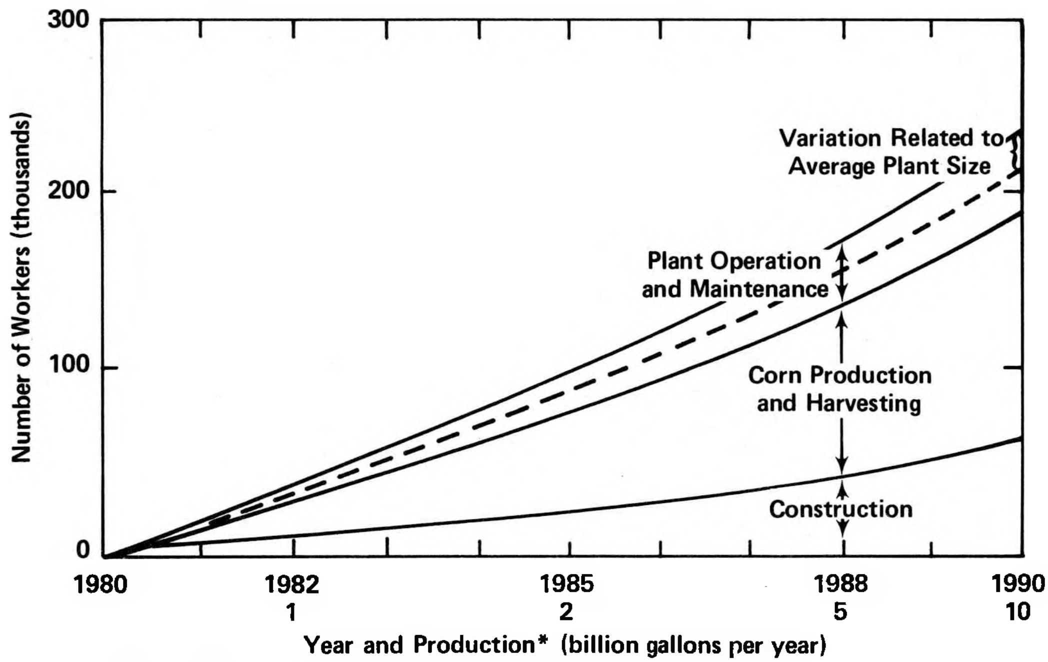
In addition to numerous jobs for unskilled workers, a sizable number of skilled and semiskilled workers will be employed in biomass energy-related activities. Some formal education, training, or licensing requirements must be satisfied for many of these individuals, especially boiler operators, turbine operators, skilled craftworkers, clerical workers, chemists, laboratory technicians, and foresters. Supervisors, managers, and administrative personnel may also need some formal education or appropriate experience.

At the national level, employment related to biomass energy will represent only a very small portion of the employment in any specific occupational category. Consequently, existing colleges, universities, trade and technical schools, and apprenticeship programs that prepare workers for the appropriate occupations will have no special difficulties meeting demand created by biomass energy growth. In regions where biomass energy is heavily concentrated, spot shortages may develop, particularly for foresters, forestry technicians, chemists, and laboratory technicians. Some specific training for process operators in alcohol-fuel plants and other biomass chemical conversion facilities may prove necessary if demand grows. Current employment patterns suggest, however, that this need can be met by adding a few properly designed courses to existing vocational-technical school programs.

Comments

The micro-level analysis of employment in biomass firms, including the discussion of staffing patterns by occupation and skill requirements, should remain valid until altered by technological innovation or change in the industry. The regional and national projections of employment growth through 1990 and 2000, which are tied to optimistic production estimates, do need revision in light of the new level of federal R&D expenditures in the early 1980s. However, other tables and graphs in the reports show the relationship between various levels of biomass production and number of workers employed without predicting what the level of production will be in any given year.

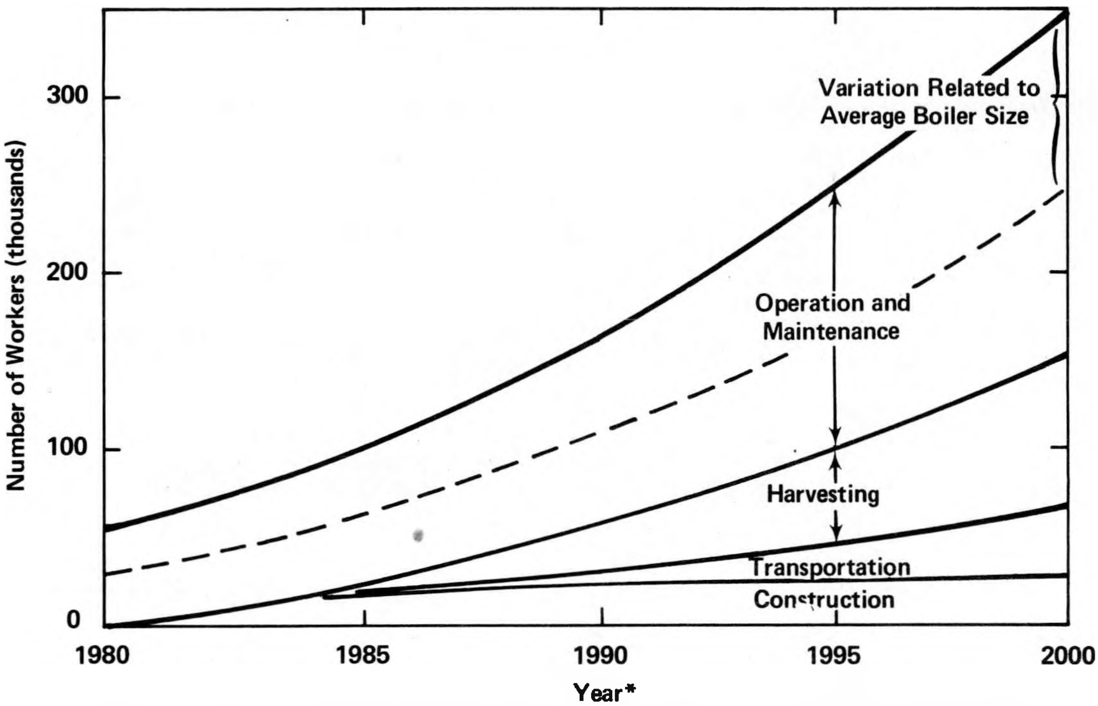
Figure 32. National Employment Potential Related to the Production of 10 Billion Gallons* of Ethanol from Corn by 1990



*Production goals correspond to those of the Office of Alcohol Fuels, DOE.

Sources: Oak Ridge Associated Universities, *Some Employment and Earnings Implications of Regional Biomass Energy Utilization: New England and the Cornbelt States* (Oak Ridge, Tennessee: 1981); and Oak Ridge Associated Universities, *Education and Training Implication of Biomass Energy System Use* (Oak Ridge, Tennessee: 1981).

Figure 33. National Employment Potential Related to Production of 5 Quads of Energy by Direct Combustion of Wood by 2000



* Assumes that increased use of wood by wood products industry accounts for an additional 0.5 quad by 1990 and 1.0 quad by 2000. The remaining 4.0-4.5 quads are derived from the combustion of newly harvested wood chips.

Sources: Oak Ridge Associated Universities, *Some Employment and Earnings Implications of Regional Biomass Energy Utilization: New England and the Cornbelt States* (Oak Ridge, Tennessee: 1981); and Oak Ridge Associated Universities, *Education and Training Implication of Biomass Energy System Use* (Oak Ridge, Tennessee: 1981).

NOTES

[1]See U.S. Department of Energy, *Federal Energy Programs: FY 1983 Budget Highlights* (Washington, D.C.: USDOE, 1982).

[2]The preliminary estimates of B.S. and M.S. scientists and engineers working in energy-related activities that are presented in the first section of this report were produced by a National Science Foundation model developed by Mathematica Policy Research. The estimates were obtained when this NSF model was applied to the results of two series of surveys sponsored by NSF and DOE's Office of Energy Research. These are the (1) National Surveys of Natural and Social Scientists and Engineers for 1972, 1974, 1976, and 1978, which were developed from the special survey of experienced workers in the 1970 census; and (2) Surveys of Recent Science and Engineering Graduates receiving their degrees between 1972 and 1977. The Recent Graduates Surveys were conducted in 1976, 1978, and 1979. The estimates of Ph.D.'s working in energy-related activities were obtained from the 1975, 1977, and 1979 Surveys of Doctoral Scientists and Engineers, also sponsored by NSF and DOE.

[3]While the Surveys of Doctoral Scientists and Engineers allow several detailed breakdowns, not all of the breakdowns of interest in this report are available for B.S. and M.S. scientists and engineers from the NSF model. Consequently, when some analyses of bachelor's and master's recipients were required (such as by energy sector or for field switching), only the results of the Survey of Recent B.S. and M.S. Science and Engineering Graduates were used. Since this survey series does not include "experienced" workers (i.e., those receiving their highest degree before 1972), its results provide information predominantly on the behavior of new graduates entering the professional workforce in the middle of the 1970s.

[4]National Academy of Sciences, National Research Council, *Summary Report 1980: Doctorate Recipients from United States Universities* (Washington, D.C.: National Academy Press, 1981).

[5]U.S. Department of Energy, Energy Information Administration, *1981 Annual Report to Congress, Vol. 3: Energy Projections* (Washington, D.C.: USGPO, 1982), pp. 55-77; National Petroleum Council, *Materials and Manpower Requirements for Oil and Gas Exploration and Production--1979-1990* (Washington, D.C.: National Petroleum Council, 1979), Appendix J; and Institute of Nuclear Power Operations, "A Survey of Occupational Employment in the Nuclear Power Industry," Progress Report #1, 1981, summarized in *Update: Nuclear Power Program Information and Data* (Washington, D.C.: USDOE, Office of Coordination and Special Projects and Office of Nuclear Reactor Programs, July-September 1981), pp. 62-70.

[6]National Petroleum Council, *Materials and Manpower Requirements*, Appendix J.

[7]A slight change in the wording of the Ph.D. survey made it somewhat easier in 1979 than in 1975 for teachers to select energy as their primary area of professional interest. For a fuller explanation, see U.S. Department of Energy, *Doctoral Scientists and Engineers Working in Energy-Related Activities, 1979*, prepared by R.B. Garey and S.E. Bell, Oak Ridge Associated Universities (Washington, D.C.: USDOE, 1982), footnote 31.

[8]U.S. Department of Energy, Office of Energy Research, *DOE Research and Development and Field Facilities* (Washington, D.C.: USGPO, 1979).

[9]Data from the American Association of Engineering Societies, reported in M. G. Finn, A. H. Hansen, and P. A. Harr, *Manpower Requirements and Supply in Magnetic Fusion Energy, 1981-2000*, prepared for U.S. Department of Energy, Office of Fusion Energy (Oak Ridge, Tenn.: Oak Ridge Associated Universities, 1981).

[10]"Companies Provide Funds for Two-Year Post: 'Staff Executive' to Tackle Faculty Shortage," *Engineering Education News* 7(June 1981):1; National Petroleum Council, *Materials and Manpower Requirements*, Appendix J; Steven Kahne, "A Crisis in Electrical Engineering Manpower," *IEEE Spectrum* (June 1981):50-52; Jack Magarrell, "20 Pct. of Science-Faculty Members Who Leave Departments Take Jobs Outside Higher Education, An NSF Study Reveals," *Chronicle of Higher Education* 23(December 2, 1981):1.

[11]U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (February 1982):76,85; Congressional Quarterly, Inc., *Energy Policy*, 2nd. ed. (Washington, D.C.: Congressional Quarterly, Inc., 1981), p. 29.

[12]National Petroleum Council, *Materials and Manpower Requirements*, Appendix J.

[13]U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (February 1982):76.

[14]Ibid.; W.A. Rosenbaum, *Energy, Politics, and Public Policy* (Washington, D.C.: Congressional Quarterly Press, 1981), pp. 146-148.

[15]Compare the estimates in the National Petroleum Council, *Materials and Manpower Requirements*, with the actual figures for 1980 and 1981 in the U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (February 1982):54,55.

[16]G.N. Wright, "Engineers Salaries in 1981," *Professional Engineer* (July 1981):21-27; D. Cowan and R. Williams, "U.S. Shortage of Skilled Personnel Becomes Acute," *Oil and Gas Journal* (December 15, 1980):27-31.

[17]National Petroleum Council, *Materials and Manpower Requirements*, Appendix J.

[18]Congressional Quarterly, Inc., *Energy Policy*, p. 70.

[19]U.S. Department of Energy, Energy Information Administration, *1981 Annual Report to Congress*, pp. 80, 81.

[20]Congressional Quarterly, Inc., *Energy Policy*, p. 69.

[21]U.S. Department of Energy, Office of Education, Business and Labor Affairs, *Assessment of the Labor Impacts of the Commercialization of Coal Gasification Systems*, prepared by J.E. Lamson and T.D. Donakowski, the Institute of Gas Technology (Washington, D.C.: USDOE, 1979).

[22]J.I. Rosenberg, M.S. Mendis, D.M. Medville, B.A. Stokes, J.D. Reierson, and P.L. Cuminskey, *Manpower for the Coal Mining Industry: An Assessment of Adequacy through the Year 2000*, 2 vols., prepared for the U.S. Department of Energy (McLean, Va.: The MITRE Corporation, 1980).

[23]Electric Power Research Institute, *The Labor Outlook for the Bituminous Coal Mining Industry*, prepared by Harold Wool and J.B. Ostbo, The Conference Board (Palo Alto, California: Electric Power Research Institute, 1980).

[24]U.S. Department of Energy, Office of Energy Research, *Occupational and Training Requirements for Expanded Coal Production*, prepared by Harold Wool, The Conference Board (Washington, D.C.: USDOE, 1982).

[25]U.S. Department of Energy, Office of Education, Business, and Labor Affairs, and U.S. Department of Labor, Employment and Training Administration, *Determinants of Coal Mine Labor Productivity Change*, prepared by J.G. Baker and W.L. Stevenson, Oak Ridge Associated Universities (Washington, D.C.: USGPO, 1979).

[26]U.S. Department of Energy, Energy Information Administration, *Annual Report to Congress, 1980, Vol. 3: Forecasts* (Washington, D.C.: USGPO, 1981), pp. 73-75.

[27]U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (February 1982):74.

[28]U.S. Department of Energy, Energy Information Administration, *1981 Annual Report to Congress*, p. 51.

[29]Ibid; pp. 45-51.

[30]R.C. Johnson, "Occupational Employment in Nuclear Power Utilities," (Oak Ridge, Tenn.: Oak Ridge Associated Universities, working paper, 1981).

[31]U.S. Department of Energy, Office of Energy Research, *A Study of the Adequacy of Personnel for the U.S. Nuclear Program*, prepared by J.F. Clarke (Washington, D.C.: USDOE, 1981).

[32]Ibid.; see also Jon Payne, "Nuclear Employment: More People Needed," *Nuclear News* 24 (November 1981):51.

[33]M.G. Finn, A.H. Hansen, and P.A. Harr, *Manpower Requirements and Supply for Magnetic Fusion Energy, 1981-2000*, p. 37.

[34]The figures given in this paragraph are based on information given in U.S. Department of Energy, Office of Education, Business, and Labor Affairs, and Office of Solar Applications, *Solar Energy Employment and Requirements 1978-1985*, prepared by G.W. Levy and Jennifer Field, Battelle Columbus Laboratories (Washington, D.C.: USDOE, 1980).

[35]U.S. Department of Energy, Office of Energy Research, *Geothermal Energy Employment and Requirements: 1977-1990*, prepared by R.L. Hannah and G.L. Magnum (Washington, D.C.: USDOE, 1982).

[36]J.R. Little and W.L. Stevenson, *Education and Training Implications of Biomass Energy System Use*, prepared for the U.S. Department of Energy, Office of Energy Research (Oak Ridge, Tenn.: Oak Ridge Associated Universities, 1981).

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