DOCUMENT RESUME

ED 195 445 SE 033 620

AUTHOR Finn, Michael G.; Blair, Philip
TITLE The Regional Distribution of Energy-Related Scientists and Engineers, 1976. Research Memorandum.
INSTITUTION Oak Ridge Associated Universities, Tenn.
SPONS AGENCY Department of Energy, Washington, D.C. Div. of Manpower Assessment.; Department of Energy, Washington, D.C. Office of Education, Business and Labor Affairs.
REPORT NO ORAU-146
PUB DATE Sep 78
CONTRACT EY-76-C-05-0033
NOTE 51p.
AVAILABLE FROM National Technical Information Service, U.S. Dept. of Commerce, 5285 Port Royal Rd., Springfield, VA 22161 (no price quoted).

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Differences; *Employment Patterns; Employment Projections; Employment Statistics; Energy; *Engineers; Labor Force; *Regional Characteristics; *Scientific Personnel; Surveys

ABSTRACT

Examined are several factors related to regional variations in the number of energy-related scientists and engineers and how this subgroup differs from the base group of scientists and engineers. The emphasis of this research project was to determine the influence of regional differences in industry mix and in staffing patterns within industries upon the number of energy-related scientists and engineers in a region. Sensitivity tests were performed on the 1976 National Science Foundation National Sample data on 50,000 scientists and engineers. Researchers concluded that both industry mix and staffing patterns within industries are important in explaining differences in regional distribution patterns. (Author/WB)

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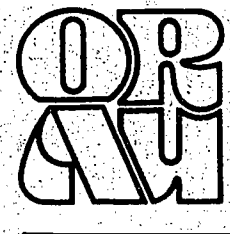

Oak Ridge Associated Universities

THE REGIONAL DISTRIBUTION OF ENERGY-RELATED SCIENTISTS AND ENGINEERS, 1976

Michael G. Finn
Philip Blair

Manpower Research Programs

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Michael G. Finn
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Research Memorandum
September 1978

Oak Ridge Associated Universities
Oak Ridge, Tennessee 37830

Prepared for the
Division of Labor and Manpower Assessment
Office of Education, Business and Labor Affairs
U.S. Department of Energy

Oak Ridge Associated Universities operates under Contract Number EY-76-C-05-0033 with the U.S. Department of Energy.

ABSTRACT

This report describes the regional distribution of scientists, engineers, energy-related scientists, and energy-related engineers. Our purpose was to acquire insight into the causes of regional differences by determining whether regional variation in industry mix or in staffing pattern within industry exerts a greater influence on the number of energy-related scientists and engineers in a region.

Sensitivity tests were made on the 1976 National Science Foundation National Sample data on 50,000 scientists and engineers, 11 percent of whom reported that their work was energy-related. We concluded that regional distribution of all scientists and engineers is strongly related to regional industry mix and only slightly affected by differing regional staffing patterns within industry. However, for energy-related scientists and engineers, both factors--industry mix and staffing patterns--are important in explaining differences in regional patterns. Neither of these determinants can be safely neglected in making energy manpower projections.

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ACKNOWLEDGMENT

Larry Blair and Jane Rall provided valuable comments and suggestions. Jane also did the computer programming for this work. They are not, however, responsible for any errors that may still exist.

INTRODUCTION

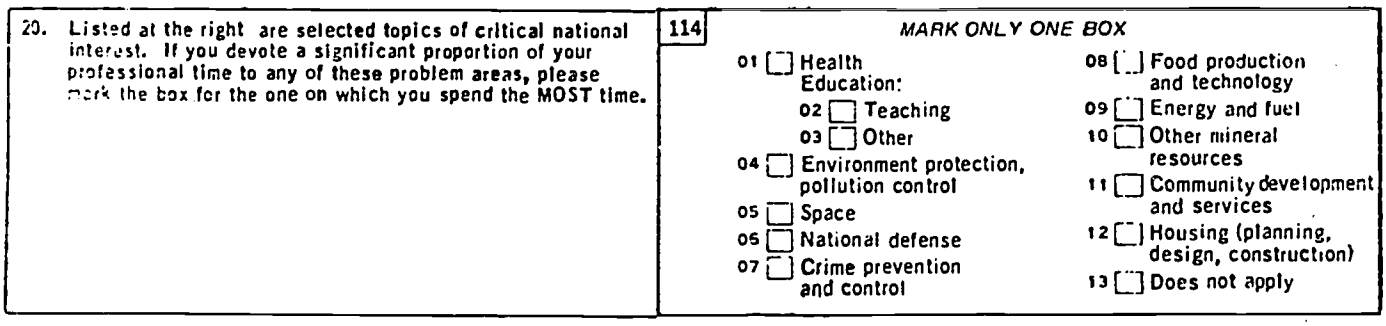
The purpose of this report is to examine several factors related to regional variations in the number of energy-related scientists and engineers and how this subgroup differs from the base group of scientists and engineers.[1]

We chose to group the factors affecting the employment of energy-related scientists and engineers into two categories, which correspond to categories used for manpower forecasting:[2]

1. Industry mix--the distribution of total employment among industries
2. Staffing patterns within industries--the distribution of employment by occupation within each industry

We tested the sensitivity of the regional distribution of energy-related scientists and engineers to industry mix on the one hand and staffing pattern changes on the other. The results provided useful insights into the reasons for the regional distribution pattern of energy-related scientists and engineers in 1976. The sensitivity analysis also allowed us to make a preliminary judgment about the feasibility of using certain shortcuts in future efforts to project energy-related employment by occupation.

The data used in this analysis are from the 1976 National Science Foundation (NSF) National Sample, which surveyed 50,000 scientists and engineers who were in the labor force in 1970. Question 20 on the NSF questionnaire permitted distinguishing specifically "energy-related" scientist and engineer employment from the rest.



20. Listed at the right are selected topics of critical national interest. If you devote a significant proportion of your professional time to any of these problem areas, please mark the box for the one on which you spend the MOST time.

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MARK ONLY ONE BOX

- 01 ☐ Health
- Education:
  - 02 ☐ Teaching
  - 03 ☐ Other
- 04 ☐ Environment protection, pollution control
- 05 ☐ Space
- 06 ☐ National defense
- 07 ☐ Crime prevention and control
- 08 ☐ Food production and technology
- 09 ☐ Energy and fuel
- 10 ☐ Other mineral resources
- 11 ☐ Community development and services
- 12 ☐ Housing (planning, design, construction)
- 13 ☐ Does not apply

Source: U.S. Bureau of the Census/NSF, *1976 National Survey of Natural and Social Scientists and Engineers.*

Figure 1. Question Used To Identify Energy-Related Scientists and Engineers from the 1976 National Sample

Note that the question permits respondents to select only one topic. Therefore, some of the persons working on the health or environmental effects of energy production can be expected to have chosen "health" or "environment protection, pollution control" instead of "energy and fuel." In effect, what results from a tabulation of persons who selected "energy and fuel" might be accurately described as the core group of energy-related manpower. It is a core group in the sense that it excludes persons who perceive their work to be more closely related to one of the other problem areas, even though it might also be energy-related.

The survey data indicate notable differences across the regions of the United States in the proportion of scientists and engineers who identified their work as being energy-related and those who did not. For example, the regions (shown in Figure 2) are ranked according to the percentage of all scientists who are energy-related (Figure 3) and of all engineers who are energy-related (Figure 4).[3] Section 1 describes regional differences between the energy-related scientists and engineers and the larger groups, and Section 2 provides some explanations of these differences.

NOTES

[1]This report is an extension of Energy-Related Scientists and Engineers: Statistical Profile from NSF National Sample, 1976 by Michael G. Finn and Jane E. Rall, Oak Ridge Associated Universities, Oak Ridge, Tennessee, May 1978.

[2]U.S. Department of Labor, Bureau of Labor Statistics, Tomorrow's Manpower Needs, Vol. 1, Washington, D.C., U.S. Government Printing Office, February 1969 (Bulletin 1606).

[3]See also Table 3.

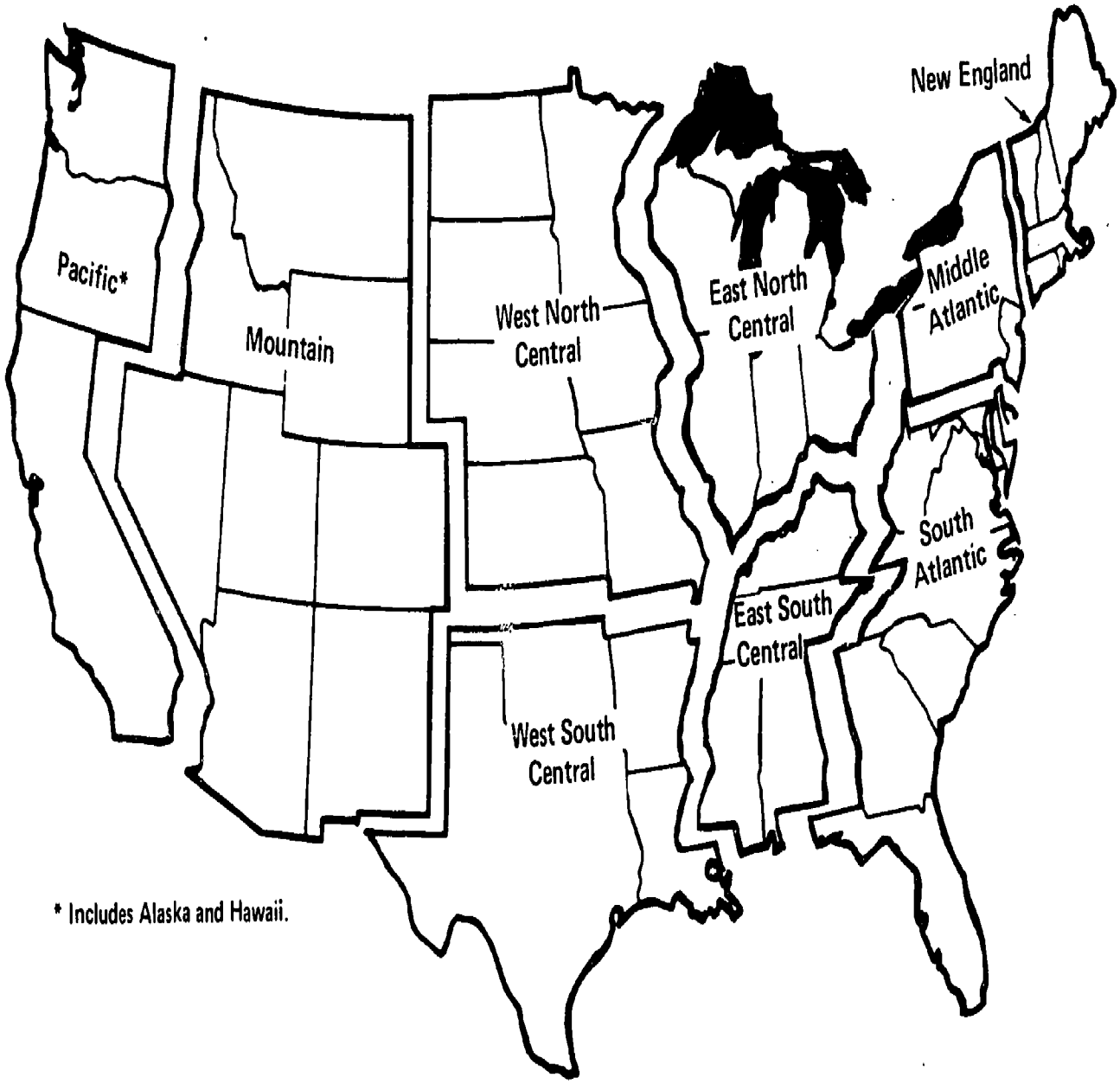
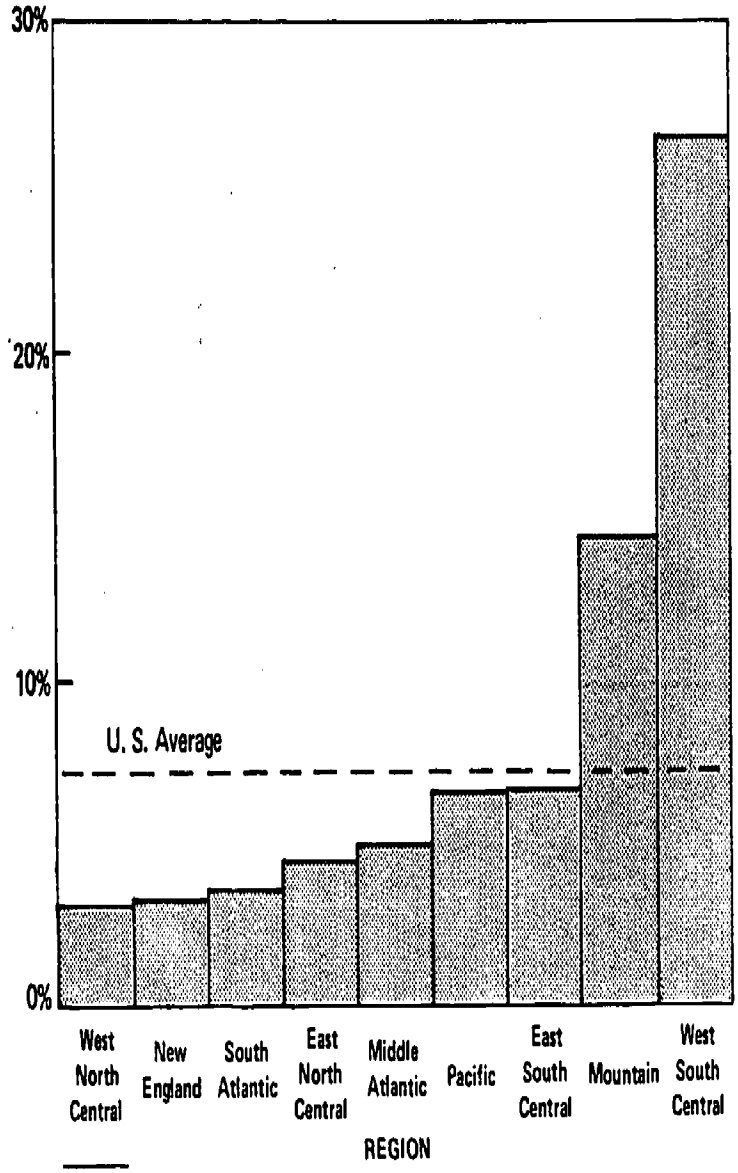
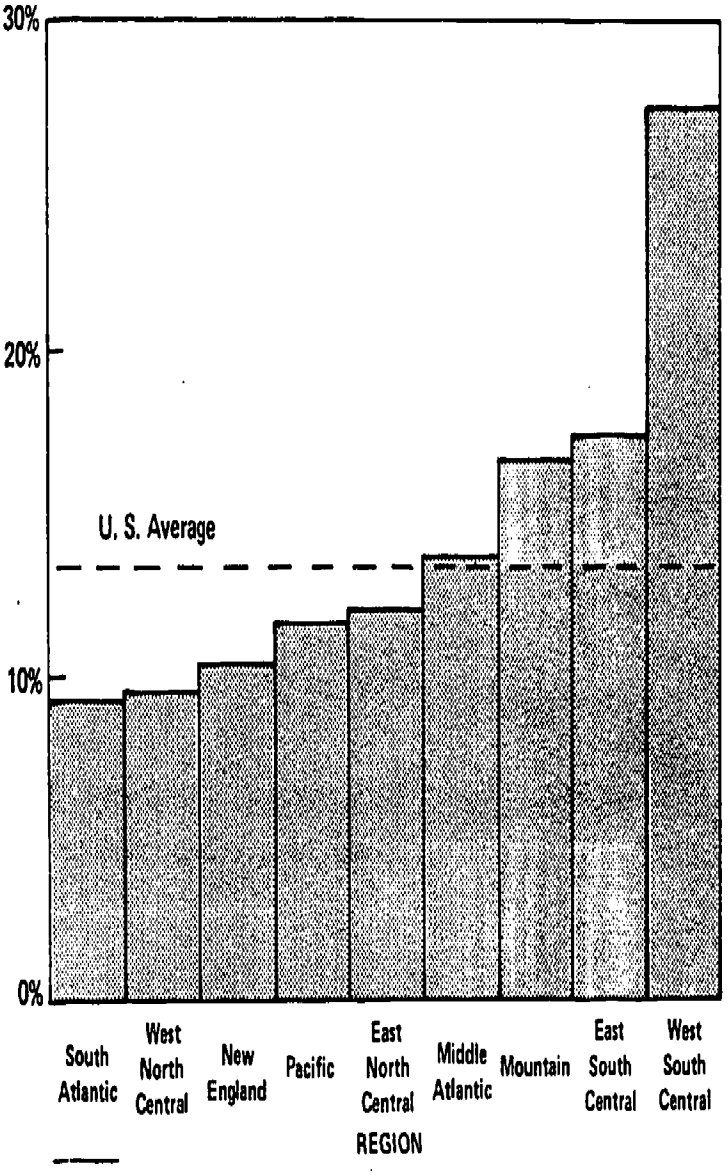


Figure 2. Classification of Regions



Source: Table 3.

Figure 3. Percentage of Energy-Related Scientists for All Industries



Source: Table 3.

Figure 4. Percentage of Energy-Related Engineers for All Industries

SECTION 1 - REGIONAL ENERGY-RELATED MANPOWER DISTRIBUTION

SCIENTISTS AND ENGINEERS

The National Sample of Scientists and Engineers indicates that differences exist in regional distribution patterns between scientists and engineers, in general, as well as between energy-related scientists and engineers.

Nationally, there are fewer than two engineers per scientist (see Table 1) but more than three energy-related engineers per energy-related scientist (Table 2). The overall range across the regions in the engineer-to-scientist ratio is also greater among the energy-related scientists and engineers than it is among all scientists and engineers. The energy-related engineer per energy-related scientist ratio reaches as high as 6.5 in New England (Table 2, Column 8). This implies that energy-related employment is richer in applied than theoretical technical personnel. The Appendix contains detailed employment breakdowns by region and field.

ENERGY-RELATED SCIENTISTS AND ENGINEERS COMPARED WITH ALL SCIENTISTS AND ENGINEERS

Table 3 shows that energy-related scientists constitute 7 percent of all scientists nationally, and energy-related engineers comprise 13 percent of all engineers. Energy-related scientists and engineers together constitute 11 percent of all scientists and engineers in the nation.

Considerable regional variation exists around the national average in the percentage of scientists and engineers who are energy-related (Table 3). Three percent of scientists in the West North Central region are in energy-related work (less than one-half the national average percentage of 7.15 percent) while over 26 percent of scientists in the West South Central region (nearly four times the national average percentage) are in energy-related employment. The South Atlantic region has 9 percent of its engineers in energy work, while the West South Central region has more than 27 percent of its engineers in energy-related work.

Table 1. Distribution of Scientists and Engineers by Region, 1976

Region	Scientists		Engineers		Total Scientists and Engineers		Ratio of Engineers to Scientists
(1)	No. (2)	% (3)	No. (4)	% (5)	No. (6)	% (7)	(8)
New England	24,721	6.7	52,221	7.9	76,942	7.5	2.11
Middle Atlantic	71,482	19.4	122,807	18.6	194,289	18.9	1.72
East North Central	59,095	16.0	116,420	17.6	175,515	17.1	1.97
West North Central	23,637	6.4	38,657	5.9	62,294	6.1	1.64
South Atlantic	62,171	16.8	87,233	13.2	149,404	14.5	1.40
East South Central	14,175	3.8	26,980	4.1	41,155	4.0	1.90
West South Central	32,120	8.7	57,772	8.8	89,892	8.7	1.80
Mountain	22,171	6.0	31,504	4.8	53,675	5.2	1.42
Pacific	55,419	15.0	121,408	18.4	176,827	17.2	2.19
Subtotal	364,991	98.9	655,002	99.3	1,019,993	99.1	1.79
Foreign and No Response	4,193	1.1	4,839	0.7	9,032	0.9	1.15
Total	369,184	100.0	659,841	100.0	1,029,025	100.0	1.79

Source: U. S. Bureau of the Census/NSF, *1976 National Survey of Natural and Social Scientists and Engineers.*

Table 2. Distribution of Energy-Related Scientists and Engineers by Region, 1976

Region	Energy-Related Scientists		Energy-Related Engineers		Total Energy-Related Scientists and Engineers		Ratio of Energy-Related Engineers to Energy-Related Scientists
	No.	%	No.	%	No.	%	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
New England	816	3.1	5,328	6.0	6,144	5.3	6.53
Middle Atlantic	3,613	13.2	16,580	18.8	20,093	17.5	4.72
East North Central	2,533	9.9	13,878	15.7	16,511	14.4	5.27
West North Central	751	2.8	3,622	4.1	4,373	3.8	4.82
South Atlantic	2,216	8.3	7,983	9.1	10,199	8.9	3.60
East South Central	927	3.5	4,627	5.2	5,554	4.8	4.99
West South Central	8,467	31.7	15,668	17.8	24,135	21.0	1.85
Mountain	3,177	11.9	5,209	5.9	8,386	7.3	1.64
Pacific	3,598	13.5	13,914	15.8	17,512	15.2	3.87
Subtotal	26,098	97.7	86,809	98.4	112,907	98.3	3.34
Foreign and No Response	610	2.3	1,378	1.6	1,988	1.7	2.26
Total	26,708	100.0	88,187	100.0	114,895	100.0	3.30

Source: U. S. Bureau of the Census/NSF, *1976 National Survey of Natural and Social Scientists and Engineers.*

Table 3. Energy-Related Scientists and Engineers as Percentage of All Scientists and Engineers By Region, 1976

Region (1)	Energy-Related Scientists as % of All Scientists[1] (2)	Energy-Related Engineers as % of All Engineers[2] (3)	Total Energy-Related Scientists and Engineers as % of All Scientists and Engineers Combined[3] (4)
New England	3.30	10.20	7.99
Middle Atlantic	4.91	13.50	10.34
East North Central	4.46	11.92	9.41
West North Central	3.18	9.37	7.02
South Atlantic	3.56	9.15	6.83
East South Central	6.54	17.15	13.50
West South Central	26.36	27.12	26.85
Mountain	14.33	16.53	15.62
Pacific	6.49	11.46	9.90
Subtotal	7.15	13.25	11.17
Foreign and No Response	14.55	28.48	22.01
Total	7.23	13.36	11.17

[1]Computed as 100 times (Table 2, Column 2) divided by (Table 1, Column 2).

[2]Computed as 100 times (Table 2, Column 4) divided by (Table 1, Column 4).

[3]Computed as 100 times (Table 2, Column 6) divided by (Table 1, Column 6).

PER CAPITA MANPOWER DISTRIBUTIONS

Total regional populations vary widely: The regional demographic "intensity" of scientists and engineers--their number per unit of total population--is shown in Table 4. Population variation across regions is controlled by using a per capita basis. Yet even on a per capita basis, there remains a twofold range in the number of scientists per 1000 people and in engineers per 1000 people. This range indicates that the regional distribution of scientists and engineers is only partially linked to regional population distribution.[1]

Regional variations in the number of energy-related scientists and engineers per unit of population are even greater than the regional variations for all scientists and engineers per unit of population (compare Table 5 with Table 4). In Table 5 there is a ninefold range in the number of energy-related scientists per 1000 people, from 0.045 in the West North Central region to 0.40 in the West South Central region. The upper extreme is due partly to a large number of scientists employed in the petroleum industry in the West South Central region.

NOTES

[1]Regional nonagricultural employment was also considered as a possible explanation of technical employment per region. But 1976 nonagricultural employment in each region was a relatively constant proportion (about 37 percent) of total regional population, with only a 4 percent standard deviation about the mean. The regional distribution of scientists and engineers per unit of nonagricultural employment would therefore add little to the explanation than that already provided by population distribution.

Table 4. Regional Population
and Scientists and Engineers per 1000 People, 1976

Region	1976 Population (1000)	1976 Regional Population Percentage	Scientists per 1000 of 1976 Population	Engineers per 1000 of 1976 Population	Scientists and Engineers per 1000 of 1976 Population
New England	12,221	5.69	2.02	4.27	6.30
Middle Atlantic	37,282	17.37	1.92	3.29	5.21
East North Central	40,934	19.07	1.44	2.84	4.29
West North Central	16,805	7.83	1.41	2.30	3.71
South Atlantic	33,990	15.83	1.83	2.57	4.40
East South Central	13,661	6.36	1.04	1.97	3.01
West South Central	21,204	9.88	1.51	2.72	4.24
Mountain	9,833	4.58	2.25	3.20	5.46
Pacific	28,729	13.38	1.93	4.23	6.16
Total	214,659	100.00	1.70[a]	3.05[b]	4.75[c]

Source: U. S. Bureau of the Census, *Statistical Abstract of the United States*, 1977 (98th edition) Washington, D.C., Table 10, p. 11.

[a]Based on 364,991, U.S. domestic subtotal in Table 1, Column 2.

[b]Based on 655,002, U.S. domestic subtotal in Table 1, Column 4.

[c]Based on 1,019,993, U.S. domestic subtotal in Table 1, Column 6.

Table 5. Energy-Related Scientists and Engineers per 1000 People, 1976

Region	Energy-Related Scientists per 1000 People	Energy-Related Engineers per 1000 People	Energy-Related Scientists and Engineers per 1000 People
New England	0.0668	0.436	0.503
Middle Atlantic	0.0942	0.445	0.539
East North Central	0.0619	0.339	0.403
West North Central	0.0447	0.216	0.260
South Atlantic	0.0652	0.235	0.300
East South Central	0.0679	0.339	0.407
West South Central	0.399	0.739	1.138
Mountain	0.323	0.530	0.853
Pacific	0.125	0.484	0.610
Total	0.122[a]	0.404[b]	0.526[c]

Source: Tables 2 and 4.

[a]Based on 26,098 subtotal in Table 2, Column 2.
[b]Based on 86,809 subtotal in Table 2, Column 4.
[c]Based on 112,907 subtotal in Table 2, Column 6.

SECTION 2 - DETERMINANTS OF REGIONAL ENERGY MANPOWER DISTRIBUTION

The tabulations given in the tables in the preceding section show the number of energy-related and all scientists and engineers in each region in 1976. We noted that for the total, the distribution pattern is fairly regular, i.e., the ratio of scientists to engineers does not vary much among regions. For the energy-related, however, this is not so. The regional distribution of energy-related scientists is not highly correlated with the distribution of energy-related engineers. Below, we examine some factors that help explain these regional variations.

POPULATION BASELINE

A way of stating the extent to which total regional population is linked to the number of regional scientists and engineers and also to the energy-related scientist and engineer populations is by means of the simple correlation coefficient. Using regional percentage of population (Table 4) as one variable and regional percentage of scientists/engineers from Table 2, columns 3 and 5, respectively, or energy-related scientists or engineers from Table 3, as the other, the correlation coefficients are

Table 6. Correlation Coefficients

Correlate of Percentage Population in Region	Simple r
Percentage scientists in region	0.94
Percentage engineers in region	.91
Percentage energy-related scientists in region	.17
Percentage energy-related engineers in region	.71

The greater association of population with energy-related engineers (0.71) than energy-related scientists (0.17) perhaps indicates that the applied work of energy-related engineers is tied more to home and commercial needs related to population than are activities of energy-related scientists. However, energy-related engineers ($r = 0.71$) are less associated with the population than are all engineers, for whom the r was 0.91. In

comparison with all scientists (for whom the correlation coefficient r was 0.94), the energy-related scientists are obviously very much less related to the population base.

The estimations reported in Tables 7 and 8 assume that the number of regional scientists and engineers and regional energy-related scientists and engineers are proportional to the region's share of the total national population, to establish a baseline computation with which later estimates can be compared. For all scientists and engineers, the weighted average of the absolute prediction errors is 15.6 percent for scientists and 18.1 percent for the engineers (Table 7).

For energy-related scientists and engineers, estimation errors are seen in Table 8 to be 62 percent for energy-related scientists and 29 percent for energy-related engineers, confirming that population alone is only a modest predictor of energy-related engineer distribution and a much less satisfactory predictor for energy-related scientists. The correlation coefficients also point to this conclusion.

METHODOLOGICAL SUMMARY

We conducted a series of eight sensitivity analyses to try to isolate the factors that best explain the variation in the regional distribution of both energy-related and all scientists versus engineers. The factors examined are summarized in two categories:

1. Industry mix--the distribution of total employment among industries
2. Staffing patterns within industry--the distribution of employment by occupation within each industry

We already know that the West South Central region (Texas, Oklahoma, etc.) has a high proportion of energy-related scientists. This could be due to industry mix (e.g., a lot of employment in the petroleum industry) or to unusual staffing patterns in each industry (e.g., if some or all of the West South Central industries tended to employ more scientists as a percentage of all scientists and engineers than are employed by the same industries in other regions).

Table 7. Estimated Regional Scientists and Engineers Based on National Per Capita Average and Percentage Deviation of Estimate from Actual, 1976

Region (1)	Estimated Number		% Prediction Error	
	Scientists (2)[a]	Engineers (3)[b]	Scientists (4)	Engineers (5)
New England	20,780	37,291	-15.9	-28.6
Middle Atlantic	63,392	113,761	-11.3	- 7.4
East North Central	69,601	124,904	17.8	7.3
West North Central	28,574	51,278	20.9	32.6
South Atlantic	57,794	103,716	- 7.0	18.9
East South Central	23,228	41,685	63.9	54.5
West South Central	36,054	30,004	12.2	12.0
Mountain	16,719	64,700	-24.6	- 4.8
Pacific	48,849	87,663	-11.9	-27.8
Total	364,991	655,002	15.6[c]	18.1[c]

Source: Tables 1 and 4 for scientists, engineers, and population by region.

[a]Column 2 from (364,991/214,659) times regional population in thousands.

[b]Column 3 from (655,002/214,659) times regional population in thousands.

[c]Weighted average of absolute errors.

Table 8. Estimated Regional Energy-Related Scientists and Engineers Based on Regional Share of National Population and Percentage Difference from Actual, 1976

Region	Estimated Energy-Related Scientists[a]	Estimated Energy-Related Engineers[b]	% Difference Scientists	% Difference Engineers
New England	1,486	4,942	82.1	- 7.2
Middle Atlantic	4,533	15,077	29.0	- 9.1
East North Central	4,977	16,554	96.5	19.3
West North Central	2,043	6,796	172.0	87.6
South Atlantic	4,132	13,746	85.5	72.2
East South Central	1,661	5,525	79.2	19.4
West South Central	2,578	8,575	-69.6	-45.3
Mountain	1,195	3,977	-62.4	-23.7
Pacific	3,493	11,618	- 2.9	-16.5
Total	26,098	86,810	61.8[c]	28.8[c]

[a]Estimates scientists in Table 7 x 0.0715 (see Table 3).

[b]Estimated engineers in Table 7 x 0.1325 (see Table 3).

[c]Weighted Average of absolute differences.

The methodology we used makes use of identities similar to Equation 1 where the real number of scientists (S_{ri}) in a region (r) and industry (i) is thought of as the product of three successive terms,

$$S_{ri} = (S+E)_r \times \frac{(S+E)_{ri}}{(S+E)_r} \times \frac{S_{ri}}{(S+E)_{ri}} \qquad (1)$$

Regional population pool of interest — Industry mix — Staffing pattern within industry

The sensitivity technique used here involves substituting a hypothetical value for the actual value in one of the terms in this equation. When the second term, industry mix, is replaced by the national average value for that term, the procedure tests sensitivity to changes in industry mix. When the third term, staffing pattern, is replaced by the national average value for that term, the procedure tests for sensitivity to differences in staffing patterns within industries.

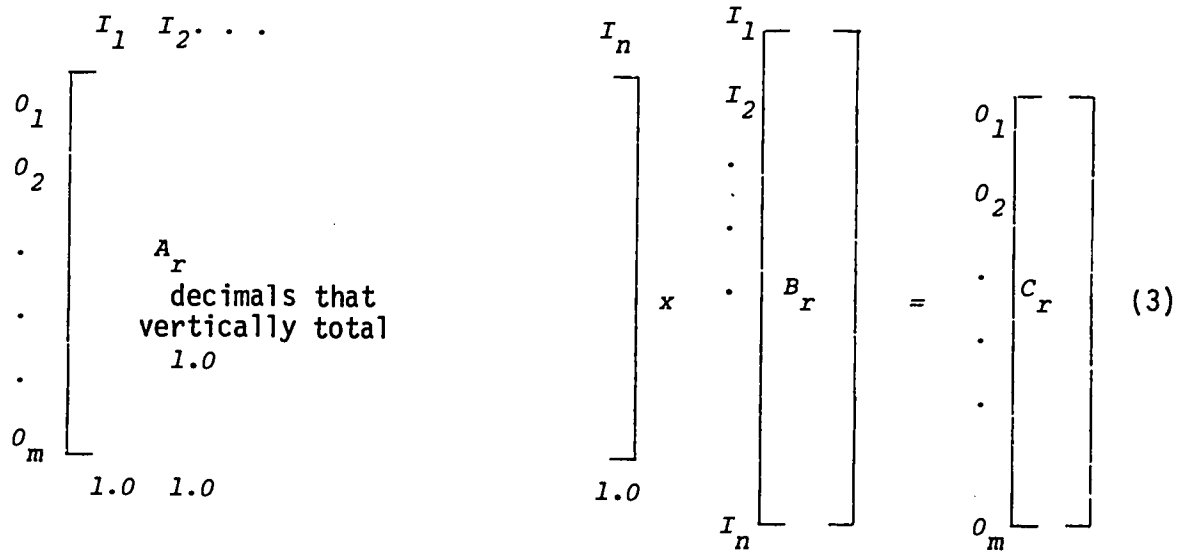
If an estimate using the national average in a calculation deviates considerably from the real value, we would say the manpower calculation described by the equation is highly sensitive to the term that was replaced by the national average. In that case, it would be necessary to use quite accurate values for that term in future manpower estimating.

If, on the other hand, substituting the national average for the real regional data in one of the terms does not make much difference in the number of persons, then we would say the estimate of the number of persons produced by the equation is not very sensitive to the term that was replaced by the national average. In future estimating, it would then not be crucial to use accurate values for the term that was replaced by the national average in the test. In other words, the equation would be robust to variations in the replaced term or the computation could tolerate fairly gross estimates in the replaced term and still give good results.

The two types of sensitivity analyses carried out in this report can be seen in a broader manpower framework used in the Bureau of Labor

Statistics manpower forecasting technique. In the Bureau's method, matrix multiplication is used to convert forecasts of employment by industry into forecasts of employment by occupation. In the technique, an industry-occupation matrix A is multiplied by an industry-mix column matrix B to yield an occupational composition column matrix C.
Thus, for any region r,

$$A_r \times B_r = C_r \qquad (2)$$



(3)

Industry-occupation matrix A applicable to region r

Industry mix column matrix B: number of employees in region r broken down by industry $I_1 \ldots I_n$

Occupational composition column matrix C: number of employees in region r broken down by occupation $O_1, \ldots O_m$

In one sensitivity test, we replace the actual regional industry-occupation matrix A_r with the national average industry-occupation matrix; this procedure tests the sensitivity of employment to staffing patterns within industry. In the other test, we replace the actual regional industry mix B_r with the national average industry mix of employment, while

using the actual industry-occupation matrix A_r that applies to the particular region. This tests the sensitivity of employment to industry mix.

In the results of these tests we look at deviations from the actual known regional employment due to the substitution of national for regional data in one of the terms. More specifically, we calculate the deviation between the known employment in each region and the employment figure calculated in the sensitivity test. We take the weighted average of the absolute deviations calculated for each of the nine regions as defined by the Bureau of the Census. This weighted average is the statistic we use to summarize the results of the sensitivity test.

ACCOUNTING FOR INDUSTRY MIX

Why is the regional distribution of energy-related scientists and engineers different from that of scientists and engineers in general, as we have observed in Section 1? The first reason, which we have already mentioned, is the obvious effect of population variation (see Figures 3 and 4). We used proportions of population relative to regional population rather than absolute numbers of persons in arriving at the figures plotted in the bar graphs.

However, regional variation in the number of per capita scientists and engineers, especially among the energy-related scientists and engineers, still remains. In seeking an explanation, we also mentioned that the regions of the country are known to differ to some extent in the numbers of scientists and engineers and energy-related scientists and engineers because the regions have different industries, or, in some cases, the same industries but in different proportions. If New England had the same emphasis on petroleum extraction as the Southwest did, then New England would probably have a different number of energy-related scientists and engineers than it now has.

We made the calculations described by Equations 4 through 7 to provide estimates of the extent to which regional variations in industry mix can account for regional variations in the numbers of energy-related and all scientists and engineers. Table 9 contains the results of these calculations.

Table 9. Sensitivity of Regional Scientists, Engineers, Energy-Related Scientists, and Energy-Related Engineers to Industry Mix, 1976

Region	Actual[a]	Predicted	Error	% Error
Scientists				
New England	23,340	24,668	1328	5.38
Middle Atlantic	66,811	65,573	-1238	-1.89
East North Central	55,725	59,197	3472	5.86
West North Central	22,344	21,766	-578	-2.65
South Atlantic	58,694	51,273	-7421	-14.47
East South Central	13,645	12,151	-1494	-12.29
West South Central	30,456	29,937	-519	-1.73
Mountain	20,978	17,996	-2982	-16.56
Pacific	52,496	59,447	6951	11.69
Weighted average of absolute differences				7.75
Engineers				
New England	48,255	46,877	-1378	-2.94
Middle Atlantic	114,495	115,732	1237	1.07
East North Central	108,983	105,510	-3473	-3.29
West North Central	37,102	37,638	536	1.43
South Atlantic	79,700	87,120	7420	8.52
East South Central	24,860	26,354	1494	5.67
West South Central	52,938	53,457	519	0.97
Mountain	29,268	32,249	2981	9.24
Pacific	113,475	106,523	-6952	-6.53
Weighted average of absolute differences				4.20
Energy-Related Scientists				
New England	816	1,728	912	52.77
Middle Atlantic	3,488	3,899	411	10.54
East North Central	2,607	3,430	823	24.00
West North Central	751	1,138	387	34.01
South Atlantic	2,188	2,637	449	17.03
East South Central	915	851	-64	-7.52
West South Central	8,302	3,881	-4421	-113.91
Mountain	3,165	1,987	-1178	-59.25
Pacific	3,543	4,283	740	17.28
Weighted average of absolute differences				54.57
Energy-Related Engineers				
New England	5,328	6,079	751	12.36
Middle Atlantic	16,398	16,446	48	0.29
East North Central	13,743	13,862	119	0.86
West North Central	3,622	4,278	656	15.34
South Atlantic	7,949	9,755	1806	18.51
East South Central	4,563	4,721	158	3,34
West South Central	15,382	10,625	-4757	-44.77
Mountain	5,077	5,039	-38	-0.76
Pacific	13,788	16,244	2456	15.12
Weighted average of absolute differences				13.99

[a]Nonresponses have been eliminated, making the totals somewhat different from Table 1.

Each for $r = 1,...9$ regions

$$\text{Scientists:} \quad \hat{S}'_r = \sum_i (S+E)_r \times \frac{(S+E)_{ni}}{(S+E)_n} \times \frac{S_{ri}}{(S+E)_{ri}} \qquad (4)$$

$$\text{Energy Scientists:} \quad \hat{ES}'_r = \sum_i (S+E)_r \times \frac{(S+E)_{ni}}{(S+E)_n} \times \frac{ES_{ri}}{(S+E)_{ri}} \qquad (5)$$

$$\text{Engineers:} \quad \hat{E}'_r = \sum_i (S+E)_r \times \frac{(S+E)_{ni}}{(S+E)_n} \times \frac{E_{ri}}{(S+E)_{ri}} \qquad (6)$$

$$\text{Energy Engineers:} \quad \hat{EE}'_r = \sum_i (S+E)_r \times \frac{(S+E)_{ni}}{(S+E)_n} \times \frac{EE_{ri}}{(S+E)_{ri}} \qquad (7)$$

where ES = energy-related scientists
EE = energy-related engineers

If we had used the actual industry mix in each region, we would have calculated the actual (known) number of scientists in each region. However, by substituting the national industry mix for the actual industry mix in each region, we calculate a hypothetical estimate that differs from the actual in every region. Taking the weighted average of these differences in each region is a way of summarizing the importance of industry mix in determining the regional number of scientists. The weighted average difference is 7.8 percent for scientists, indicating that the regional distribution of scientists is somewhat sensitive to the industry mix.

The same procedure can "predict" the number of energy-related scientists in each region, but with much less accuracy: the hypothetical estimate that comes from using the national industry mix instead of the appropriate regional industry mix differs on average by 54.6 percent (Table 9). We must conclude that the regional distribution of energy-related scientists is very sensitive to variations in the industrial mix.

For all engineers and energy-related engineers, employment is less highly concentrated in a few key industries (especially when compared with energy-related scientists). As a result, the regional distribution of engineering employment is not as sensitive to variations in the industrial mix of employment. This is illustrated by the results of the sensitivity tests shown in Table 9. When the national industrial mix is used instead of the actual industrial mix in each region, the error is only 4.2 percent for engineers but 14.0 percent for energy-related engineers.

ACCOUNTING FOR SCIENTIST/ENGINEER STAFFING PATTERNS WITHIN INDUSTRY

In addition to the industry mix effect just discussed, there is another cause of manpower differences from region to region--the regionally differing staffing pattern or occupational composition among the scientists *within* a given industry. The petroleum industry in Texas, for instance, has a different proportion of scientists to engineers than does the same industry in California.

We made the calculations described by the following equations to provide estimates of the effects of regional variations in staffing patterns within industry on the numbers of energy-related and all scientists and engineers in each region.

Each for $r = 1,...9$ regions

$$\text{Scientists: } \hat{S}''_r = \sum_i (S+E)_r \times \frac{(S+E)_{ri}}{(S+E)_r} \times \frac{S_{ni}}{(S+E)_{ni}}$$

$$\text{Engineers: } \hat{E}''_r = \sum_i (S+E)_r \times \frac{(S+E)_{ri}}{(S+E)_r} \times \frac{E_{ni}}{(S+E)_{ni}}$$

$$\text{Energy Scientists: } \hat{ES}''_r = \sum_i (S+E)_r \times \frac{(S+E)_{ri}}{(S+E)_r} \times \frac{ES_{ni}}{(S+E)_{ni}}$$

$$\text{Energy Engineers: } \hat{EE}''_r = \sum_i (S+E)_r \times \frac{(S+E)_{ri}}{(S+E)_r} \times \frac{EE_{ni}}{(S+E)_{ni}}$$

These equations are similar to Equations 4 through 7 in some respects. The difference is that in Equations 4 through 7, we used the national industrial mix with the correct regional staffing patterns, and now it is vice versa. That is, we now use the regional industrial mix with national staffing pattern in each industry. This procedure gives us insight into the importance of staffing patterns in explaining the regional distribution of energy-related scientists and engineers.

The results of the calculations (Table 10) indicate that the distribution of engineers and scientists by region is not very sensitive to staffing pattern differences from one region to another. That is, estimates made using national instead of regional staffing patterns differed from the actual number of engineers in each region by a weighted average of only 1.8 percent. For scientists the difference was only slightly larger, 3.1 percent.

However, the regional distribution of energy-related scientists and engineers is much more sensitive to staffing pattern differences. Estimates made using national instead of regional staffing patterns differed from the actual number of energy-related engineers by an average of 12.6 percent. For energy-related scientists the difference was 24.5 percent.

Table 10. Sensitivity of Regional Scientists, Engineers, Energy-Related Scientists, and Energy-Related Engineers to Variations in Staffing Patterns Within Industry, 1976

Region	Actual[a]	Predicted	Error	% Error
Scientists				
New England	23,340	24,538	1198	4.88
Middle Atlantic	66,811	65,413	-1398	-2.14
East North Central	55,725	55,112	-613	-1.11
West North Central	22,344	22,744	400	1.76
South Atlantic	58,694	56,016	-2678	-4.78
East South Central	13,645	15,727	2082	13.24
West South Central	30,456	30,721	265	0.86
Mountain	20,978	20,257	-721	-3.56
Pacific	52,496	53,960	1464	2.71
Weighted average of absolute differences				3.08
Engineers				
New England	48,255	47,057	-1198	-2.55
Middle Atlantic	114,495	115,892	1397	1.21
East North Central	108,983	109,595	612	0.56
West North Central	37,102	36,701	-401	-1.09
South Atlantic	79,700	82,378	2678	3.25
East South Central	24,860	22,778	-2082	-9.14
West South Central	52,938	52,673	-265	-0.50
Mountain	29,268	29,989	721	2.40
Pacific	113,475	112,010	-1465	-1.31
Weighted average of absolute differences				1.80
Energy-Related Scientists				
New England	816	1,191	375	31.52
Middle Atlantic	3,488	3,981	493	12.38
East North Central	2,607	3,230	623	19.29
West North Central	751	1,229	478	38.90
South Atlantic	2,188	3,144	956	30.40
East South Central	915	972	57	5.91
West South Central	8,302	6,056	-2246	-37.09
Mountain	3,165	2,399	-766	-31.94
Pacific	3,543	3,572	29	0.82
Weighted Average of absolute differences				24.53
Energy-Related Engineers				
New England	5,328	5,595	267	4.77
Middle Atlantic	16,398	16,240	-158	-0.97
East North Central	13,743	15,181	1438	9.47
West North Central	3,622	4,583	961	20.96
South Atlantic	7,949	10,603	2654	25.03
East South Central	4,563	3,355	-1208	-36.01
West South Central	15,382	12,444	-2938	-23.61
Mountain	5,077	4,820	-257	-5.32
Pacific	13,788	13,028	-760	-5.83
Weighted average of absolute differences				12.60

[a]Nonresponses have been eliminated making the totals somewhat different from Tables 1 and 2.

SECTION 3 - CONCLUSIONS AND IMPLICATIONS

Scientists and engineers are distributed unevenly in the United States. The regional variation in the number of energy-related scientists and engineers is especially high and is only weakly correlated with regional variations in total population or employment.

Two factors were examined to further explain the regional variations in energy-related manpower: industry mix and staffing patterns within industries. Table 11 summarizes the results of the sensitivity tests that were performed to measure the importance of these factors. The figures in Table 11 can be described as the percentage error that results when we oversimplify and use some kind of national average instead of a known regional characteristic, e.g., using the national industry mix instead of a known regional industry mix. Therefore, the higher the number in Table 11, the more important is a factor in explaining regional variations in the number of scientists or engineers.

Table 11 shows that both industry mix and staffing patterns are important in explaining the regional distribution of energy-related scientists and engineers. It also shows that industry mix is the more important of the two factors.

The most striking result of the sensitivity tests, however, is the difference between the energy-related scientists and engineers and all scientists and engineers. The numbers of energy-related scientists and engineers are much more sensitive to each of the factors--industry mix and staffing pattern--than are the numbers of all scientists and engineers.

The results of our study suggest that a manpower analyst wishing to make quick estimates of the numbers of scientists or engineers in a region could more safely neglect regional variations in staffing pattern within industry than industry mix variations among regions. But although an analyst could come very close to predicting the regional distribution of all scientists or engineers using only regional industry mixes, the estimates for energy-related scientists and engineers would be improved considerably by using both regional industry mix and the regional staffing pattern within each industry.

Table 11. Summary of Calculated Results, 1976 Data
(Weighted Average Absolute Percentage Difference from Actual Persons)

Test	Scientists	Engineers	Energy-Related Scientists	Energy-Related Engineers
1. Sensitivity to regional per capita occupational differences from national e.g., $\hat{S}_r = P_r (S_n/P_n)$	15.6	18.1	61.8	28.8
2. Sensitivity to regional industry mix differences from national e.g., $\hat{S}'_r = \sum_i (S+E)_r \times \frac{(S+E)_{ni}}{(S+E)n} \times \frac{S_{ri}}{(S+E)_{ri}}$	7.75	4.20	54.6	14.0
3. Sensitivity to staffing pattern within industry differences from national e.g., $\hat{S}''_r = \sum_i (S+E)_{ri} \times \frac{S_{ni}}{(S+E)_{ni}}$	3.08	1.80	24.5	12.6

Source: Tables 7 through 10.

In view of the observed substantial sensitivity of regional energy-related scientist and engineer employment to both industry mix and staffing pattern within industry, we recommend detailing the industry-occupation matrix for energy-related scientists and engineers by region. Energy manpower analysts would thereby have more reliable data than they would have by applying the national average staffing patterns within industry to the separate regions.

APPENDIX - ALL AND ENERGY-RELATED SCIENTISTS AND ENGINEERS BY FIELD AND REGION, 1976

Table A-1. Engineers and Scientists by Field and Region, 1976

	Region[a]										
	1	2	3	4	5	6	7	8	9	10	Total
All Scientists and Engineers, Total	76,942	194,289	175,515	62,294	149,404	41,155	89,892	53,675	176,827	9,032	1,029,025
Engineer, Total	52,221	122,807	116,420	38,657	87,233	26,980	57,772	31,504	121,408	4,839	659,841
Chemical	2,171	8,518	5,580	2,065	5,125	1,401	6,926	1,105	3,778	496	37,165
Civil and Architectural	5,513	13,793	14,511	6,131	12,088	4,114	7,071	5,338	17,606	418	86,583
Electrical and Electronic	11,289	27,520	18,953	8,058	17,775	5,669	9,234	6,999	28,724	1,019	135,240
Mechanical	11,148	22,486	29,312	7,374	13,656	5,463	9,248	4,802	21,296	374	125,159
Metallurgical and Materials	1,073	4,222	4,317	564	1,298	495	509	947	2,007	259	15,691
Mining and Petroleum	35	664	615	513	437	123	5,354	1,875	896	301	10,813
Nuclear	285	830	558	53	1,197	377	182	540	1,359	10	5,391
Managerial/ Administrative	6,894	14,143	14,491	4,595	11,157	2,510	5,414	3,307	11,289	837	74,637
Environmental and Sanitary	867	2,263	1,433	769	1,154	291	1,054	376	1,121	96	9,424
Operations Research Systems	1,291	2,468	1,735	224	1,662	466	499	295	3,305	192	12,137

[a]Region code

1--New England
2--Middle Atlantic
3--East North Central
4--West North Central
5--South Atlantic
6--East South Central
7--West South Central
8--Mountain
9--Pacific
10--Foreign and No Response

Table A-1. Engineers and Scientists by Field and Region, 1976 (Continued)

	Region										
	1	2	3	4	5	6	7	8	9	10	Total
Engineering, Industrial	2,139	5,344	7,122	2,241	3,202	1,191	1,735	754	4,289	78	28,095
Other Engineering	9,516	20,556	17,793	6,070	18,482	4,880	10,546	5,166	25,738	759	119,506
Scientist, Total	24,721	71,482	59,095	23,637	62,171	14,175	32,120	22,171	55,419	4,193	369,184
Mathematician and Statistician	1,450	4,209	3,955	1,218	6,003	962	2,178	1,429	3,274	298	24,976
Computer Specialist	4,089	11,894	7,424	2,546	8,250	1,663	4,069	1,645	8,277	433	50,290
Physical Scientist, Total	8,588	27,370	21,474	6,429	18,266	4,116	7,753	5,955	15,948	1,201	117,100
Chemist	5,616	20,706	17,427	5,315	12,507	3,136	6,215	3,150	9,214	554	83,840
Physicist, Astronomer	2,472	5,550	3,228	978	4,296	837	1,388	2,272	5,977	508	27,506
Other Physical Scientist	500	1,114	819	136	1,463	143	150	533	757	139	5,754
Environmental, Earth, and Marine Scientist	1,153	1,586	1,672	1,069	3,355	738	8,164	4,571	4,057	617	26,982
Earth Scientist (Includes Geology, Geophysics)	633	1,287	1,396	851	1,990	621	7,641	4,251	3,110	592	22,372

Table A-1. Engineers and Scientists
by Field and Region, 1976 (Continued)

	Region										
	1	2	3	4	5	6	7	8	9	10	Total
Other Environmental Scientist	520	299	276	218	1,365	117	523	320	947	25	4,610
Life Scientist	3,803	9,229	11,333	6,866	11,643	4,028	5,789	4,929	11,863	611	70,094
Psychologist	2,578	8,308	6,087	2,321	4,324	1,110	2,134	1,503	5,531	299	34,195
Social Scientist, Total	3,060	8,886	7,150	3,188	10,330	1,558	2.033	2,139	6,469	734	45,547
Economist	912	3,220	2,594	1,171	5,256	796	946	742	1,783	280	17,700
Other Social Scientist	2,148	5,666	4,556	2,017	5,074	762	1,087	1,397	4,686	454	27,847

Table A-2. Energy-Related Engineers and Scientists by Field and Region, 1976

	Region										
	1	2	3	4	5	6	7	8	9	10	Total
All Scientists and Engineers, Total	6,144	20,093	16,511	4,373	10,199	5,554	24,135	8,386	17,512	1,988	114,895
Engineer, Total	5,328	16,580	13,878	3,622	7,983	4,627	15,668	5,209	13,914	1,378	88,187
Chemical	359	1,593	1,002	304	905	305	2,445	314	1,220	96	8,543
Civil and Architectural	324	634	934	186	503	493	826	588	1,490	106	6,084
Electrical and Electronic	936	2,753	2,970	654	1,136	1,273	1,826	874	2,421	223	15,066
Mechanical	1,928	5,085	3,533	1,103	1,659	1,169	2,983	813	3,958	151	22,382
Metallurgical and Materials	169	574	606	51	86	122	140	157	394	25	2,324
Mining and Petroleum	12	299	342	149	329	51	4,469	884	464	179	7,178
Nuclear	181	562	481	0	772	215	80	341	887	0	3,519
Managerial/Administrative	679	2,083	1,922	592	1,438	563	1,518	681	1,248	406	11,130
Environmental and Sanitary	0	51	87	0	0	0	0	0	12	0	150
Operations Research Systems	159	387	106	0	199	0	103	131	177	0	1,262

[a]Region code:

1--New England
2--Middle Atlantic
3--East North Central
4--West North Central
5--South Atlantic
6--East South Central
7--West South Central
8--Mountain
9--Pacific
10--Foreign and No Response

Table A-2. Energy-Related Engineers and Scientists by Field and Region, 1976

	Region										
	1	2	3	4	5	6	7	8	9	10	Total
Engineering, Industrial	37	506	716	93	112	40	238	0	155	0	1,897
Other Engineering	544	2,053	1,179	490	844	396	1,040	426	1,488	192	8,652
Scientist, Total	816	3,613	2,533	751	2,216	927	8,467	3,177	3,598	610	26,708
Mathematician and Statistician	39	85	60	0	202	39	333	46	28	19	851
Computer Specialist	139	486	339	49	174	89	712	48	503	53	2,592
Physical Scientist, Total	485	2,238	1,525	323	1,044	547	1,543	988	1,791	76	10,560
Chemist	55	1,492	878	187	607	244	1,157	464	855	52	5,991
Physicist, Astronomer	357	711	459	136	308	303	337	382	872	24	3,889
Other Physical Scientist	73	35	188	0	129	0	49	142	64	0	680
Environmental, Earth, and Marine Scientist	89	345	307	344	373	187	5,723	1,991	1,041	445	10,845
Earth Scientist (Includes Geology, Geophysics)	75	333	295	293	361	187	5,723	1,991	1,030	433	10,721

Table A-2. Energy-Related Engineers and Scientists by Field and Region, 1976, (Continued)

	Region										
	1	2	3	4	5	6	7	8	9	10	Total
Other Environmental Scientist	14	12	12	51	12	0	0	0	11	12	124
Life Scientist	13	12	95	0	64	37	25	87	105	0	438
Psychologist	0	77	107	0	19	0	12	0	14	0	229
Social Scientist, Total	51	270	200	35	340	28	119	17	116	17	1,193
Economist	51	213	146	18	295	14	105	17	99	17	975
Other Social Scientist	0	57	54	17	45	14	14	0	17	0	218