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ABSTRACT

Based on data collected from a mailed survey of 280 employers engaged in solar energy activities, a study identified the characteristics of establishments engaged in solar work and the number and occupational distribution of persons working in solar energy activities in 1978, and projected solar labor requirements through 1985. The scope of the study included all types of solar energy technologies and applications (space heating and cooling, ocean thermal conversion, photovoltaic conversion, wind conversion and biomass conversion), and all phases of work (research and development, manufacturing, marketing and distribution, and installation and maintenance). The study also identified new job specialties in the solar area, and developed a methodology for projecting short- and mid-term future employment. A mail survey of 500 employees was also conducted to determine the work requirements of their jobs, their special skills, and their education and training. Detailed findings are presented along with five recommended activities for planning for future personnel needs in the solar industry. Appendixes include (1) survey questionnaires, screening form, and cover letter; (2) notes on response rate, establishment population, and nonresponse bias; (3) detailed tabulations; and (4) description of methodology used to formulate manpower projections. (KC)

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Solar Energy Employment and Requirements 1978—1985

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PREFACE

As the Nation takes steps to develop alternative energy sources, it is important to recognize the possible barriers to the development and use of these sources. One of the barriers may be a shortage of technical and skilled workers, reflecting a National shortage in specific occupations, an industry shortage of personnel trained in the particular skills of that industry, or geographic regional and local problems. By providing information on estimated future personnel requirements, a basis is established for initiating or deferring programs or actions affecting the supply of trained workers.

Toward providing information on future manpower needs, the Department of Energy, through the Manpower Assessment Program, is supporting a number of studies dealing with current and projected employment and occupational composition of the work force which will be needed for the development of new and emerging energy technologies.

We wish to acknowledge the assistance and support of others in the conduct of this study: Arthur W. Saltzman, consultant to the Department of Energy; Sheldon H. Butt, President, Solar Energy Industries Association; and, particularly, the organizations and individuals who responded to the lengthy and detailed survey questionnaires and provided the basic data for this study.

Norman Seltzer, Chief
Manpower Assessment Program

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SUMMARY AND HIGHLIGHTS

This study describes the characteristics of establishments engaged in solar energy work and the number and occupational distribution of persons working in solar energy activities in 1978. The study also projects future solar manpower requirements through 1983. The scope of the study included all types of solar energy technologies and applications (space heating and cooling, water heating, industrial process heat, thermal power, ocean thermal conversion, photovoltaic conversion, wind conversion and biomass conversion), and all phases of work (research and development, manufacturing, marketing and distribution, and installation and maintenance).

The data for the study were collected by a mail survey of employers engaged in solar energy activities. Questionnaires were sent to over 2800 establishments. Over 50 percent of those contacted responded. Detailed information was provided by 563 employers engaged in solar energy work. These employers reported the type of organization, industrial classification of their establishment, principal solar products and services, types of solar energy technologies involved, total employment and solar employment, occupations of those working in solar, number of additional solar jobs anticipated, new solar job specialities, sources of solar funding, and anticipated future commercial solar sales.

The survey responses, undeliverable mail and follow-up telephone calls indicated that there is frequent entry and exit of firms in this infant industry. It is estimated that approximately 2000 establishments (both public and private) were engaged in solar energy activities in 1978. Approximately three out of every four of these establishments were primarily working in solar space and water heating. Most establishments,

however, were involved in many different types of solar energy and in many different phases of solar work. Over 60 percent of the respondent establishments categorized themselves as private industry or business. The states with the most solar establishments were California (16 percent of the total), New York (8 percent), Massachusetts (7 percent), Colorado (4 percent), and Texas (4 percent).

Approximately 31 percent of the respondent establishments were involved in the manufacture of solar collectors or other solar products. About 23 percent provided research and development services, and 18 percent provided architectural and engineering services. Twelve percent of the respondent establishments were engaged in installation and 16 percent provided other solar-related services.

The establishments engaged in solar work tended to be small in size. Forty percent had 10 or fewer employees. Only 20 percent had over 400 employees. These larger establishments, however, employed 40 percent of all persons working in solar. The percentage of employees engaged in solar work varied inversely with the size of the establishment. That is, establishments with 20 or fewer employees had over 80 percent of their employees engaged in solar work. In contrast, establishments with more than 400 employees had less than 1 percent of their employees engaged in solar work.

Establishment size was also related to the type of solar work performed. Installation, architectural and engineering services, and miscellaneous services were performed mainly by small organizations, whereas R&D work was performed mainly by large organizations. Manufacturing work was performed by both large and small establishments. Approximately 75 percent of the solar work of large establishments was in R&D.

The total estimated number of persons working in solar in 1978 was 22,500. This figure represents all employees, both full and part-time. This figure was broken down by occupation and activity. Engineers comprised the largest occupational group among persons engaged in R&D activities. Unskilled workers made up the largest occupational group in commercial activities, and skilled workers made up the largest occupational group in installation. Engineers comprised the largest occupational group overall. The number of persons working in solar R&D was slightly

greater than the number working in solar commercial and installation activities. Sixty-five percent of all persons were employed in establishments primarily engaged in solar space and water heating.

Employers were asked to estimate the number of additional solar jobs which their establishment would add by 1981. The anticipated gain in solar employment was estimated to be 90 percent. The largest gains were anticipated for skilled workers and technicians in the fields of manufacturing and construction.

The most difficult to hire solar occupations included engineers, atmospheric scientists, systems researchers, and college instructors. The least difficult to hire solar occupations were clerical, skilled and unskilled workers.

One of the objectives of the study was to identify new job specialities in the solar area. Only one out of every four employers thought their professional, technical or skilled craft employees performed tasks that were substantially different from those traditionally performed in nonsolar jobs. Where new skills were identified, special solar design, analysis and installation skills were most frequently mentioned by employers. Thus, there appears to be some need for persons trained in the design and analysis of new solar systems, and for persons trained in installing these systems. However, these employees must be capable of performing traditional as well as purely solar work.

A methodology for projecting short and mid-term future employment was developed. The methodology is based on data provided by employers and employees, on projected Federal R&D funding, and on solar energy penetration models. The methodology was constrained by the unwillingness of employers to provide financial data on R&D funding or commercial solar sales. The lack of actual dollar figures required the use of certain assumptions about R&D productivity. Also, labor coefficients for production and installation of solar systems had to be estimated from sources other than the survey responses.

Using the methodology that was developed, solar employment in R&D activities is projected to increase from 1978 levels by 74 percent by 1981 and by 144 percent by 1983. Commercial solar employment (for those

technologies which are currently commercialized) is projected to increase from 1978 levels by 137 percent by 1981 and by 203 percent by 1983. Overall the number of persons engaged in solar energy work is projected to double by 1981, and nearly triple by 1983.

A mail survey of nearly 500 employees working in solar energy was also conducted by sampling employees within the respondent establishments. Employees were asked to describe their solar work, the number of hours worked, their education and training, and special skills needed in their job.

The number of hours worked in solar and nonsolar activities are important indicators of manpower utilization. About half of the persons working in the field were only working part-time in solar-related work. Thus, the existing manpower pool was underutilized. The average number of hours spent in solar-related work activities during the week of June 11 - 17, 1978, (an arbitrarily chosen period) was approximately 30 hours. The percentage of time spent on solar-related work was high for manufacturing employees and low for employees engaged in installation and maintenance activities.

Nearly 90 percent of the respondent employees felt that their job required special skills and knowledge. The primary source of these special skills was formal training (44 percent of respondents), practical experience (41 percent), and self-study (15 percent). A majority of the employees had not completed any formal training programs or courses in solar energy. This was true of persons working in R&D as well as persons working in installation and maintenance. Nearly 60 percent of the formal solar energy courses taken were provided by colleges and universities. The average duration was between 20 and 40 hours. Most employees felt that they needed more education and training for their work in solar, but not necessarily restricted to solar areas.

Five recommendations are presented. Periodic surveys of establishments engaged in solar energy activities should be conducted to determine employment and occupational trends. Solar energy employees should be identified in national occupational surveys to provide a more exact determination of the number and characteristics of persons engaged in solar energy work. Information concerning the supply of solar energy manpower should be

requirements for the production and installation of different types of commercially available solar energy systems should be obtained to assist in manpower projections. Finally, improved regional and state projections of future solar employment should be developed to assist regional, state, and local agencies in their planning activities.

Interest in solar energy applications has a history of peaks and valleys in the United States. Recently, of course, interest has accelerated to the point where the national effort in solar energy research and development probably exceeds one billion dollars a year. It is expected to reach several billion dollars soon when solar devices are more widely marketed.

The growing emphasis on solar energy applications implies future demands for a variety of manpower skills and capabilities, including research and development skills, analysis and design skills, manufacturing skills, and installation and maintenance skills. Many of these skills and capabilities may be available in adequate numbers through normal reallocation of manpower resulting from private sector market forces (e.g., job openings, differential wage rates, and investment decisions). On the other hand, adequate availability of some skills may require considerable advanced planning and public sector support, particularly where rapid development and implementation of new technologies is expected. Information about needed skills and capabilities, provided through manpower surveys and forecasting, aids in the formulation of government policy, and can be used in making policy decisions regarding R&D contracts, educational support, manpower training, and other programs. Manpower surveys and forecasting are especially important when anticipated manpower shortages or surpluses could act as a constraint on Federal policies or programs.

With regard to solar energy manpower, the concern is two-fold. First, the development and application of solar energy may create additional employment opportunities. This could be particularly true if the installation of solar space and water heating systems in homes and businesses were more labor intensive than conventional systems. However, the additional employment opportunities may require new skills or a different mix of skills than is currently possessed by the workforce. Second, a lack of adequately trained manpower could constrain the

development and acceptance of solar energy as an alternative energy source. For example, improperly installed and maintained solar units could lead to public reluctance to acquire such units.

OBJECTIVES

The basic purposes of this study were (a) to provide a description of the present status of the solar energy area in terms of manpower, and (b) to develop and apply a methodology for projecting manpower requirements in solar energy.

Encompassed within these two overall purposes are the following objectives:

- Identification and description of employers (private and public) engaged in solar and solar-related activities
- Collection of employment data by occupation
- Definition of new occupational specialties and changes in traditional occupations
- Analysis of the education and experience of those employed in solar and solar-related areas
- Projection of short-term and mid-term solar employment by occupation, and a development of a methodology for formulating future projections.

SCOPE

The objectives required data concerning both employers and employees engaged in solar-related activities. All types of employers (e.g., manufacturers, installers, R&D organizations, public utilities, educational institutions, etc.) were included. The study focused on professional, technical, and skilled craft occupations.

The following types of solar energy were included in the study:

- Space heating and cooling: The transmission and storage of solar thermal energy using solar collectors, some transmission medium, and storage facilities. Includes passive and active residential or commercial solar heating or cooling of human, plant or animal shelters.
- Solar water heating: The transmission and storage of solar thermal energy using solar collectors, heat exchangers, and some transmission medium. Includes passive and active residential or commercial solar water heating and swimming pool heating.
- Industrial process heat: The transmission of solar thermal energy for various industrial applications using solar collectors and some transmission medium. Includes crop dryers.
- Thermal power: The use of concentrating solar collectors, heat absorbers, boilers, and heat exchangers, etc., to generate electricity. Includes irrigation systems.
- Ocean thermal conversion: The generation of electricity by use of the temperature difference between surface and deep water.

- Photovoltaic conversion: The generation of electricity by allowing sunlight to fall upon two dissimilar substances in what is commonly called a solar cell.
- Wind conversion: The generation of energy through the use of machines consisting of revolving blades or airfoils.
- Biomass conversion: The cultivation and chemical processing (via fermentation, pyrolysis, or combustion) of terrestrial or aquatic plants for the purpose of creating direct energy, fuels, or chemical feedstocks.

The study encompassed the following phases of solar and solar-related energy work:

- Research and Development: Theoretical or experimental investigations directed toward the acquisition of new or fuller scientific knowledge of the subject studied, or systematic application of scientific knowledge directed toward the creation of new or substantially improved equipment, processes, procedures, and techniques in any area of solar energy; or prototype design and engineering of solar energy hardware components and/or systems.
- Manufacturing: The mechanical or chemical transformation of materials into components designed specifically for application in a solar energy system; also, the assembly of solar components and other materials into solar energy systems.

- Marketing and Distribution: The process of estimating the demand for a product, promoting the product, transporting the product and selling the product.
- Installation and Maintenance: Specialized activities, such as plumbing, electrical wiring, metal and glass working, etc., required to emplace or prepare solar energy components and/or systems for actual operation; also, specialized repair services required to locate or correct failures in components and/or solar energy systesm.
- Other Commercial Activities: Customer design, product testing and quality control, engineering and consulting services to licensees, experimental work needed for patent litigation, etc.

RESEARCH APPROACH

To meet the objectives of the study, the research effort was structured into five tasks: (a) developing the survey questionnaires, (b) pretesting and revising the questionnaires, (c) developing the universe list, (d) selecting the sample, and (e) conducting the survey. Each of these tasks is described below.

Developing the Questionnaires

One questionnaire and a screening form were developed for establishments involved in any type or phase of solar energy work. A second questionnaire was developed for professional, technical and skilled workers, who were engaged in solar energy activities, and who were employed by the establishments.

The purpose of the employer questionnaire was to collect detailed information on the following:

- Type of organization
- Industrial classification
- Types of solar energy that organization was involved in
- Principal solar products and services
- Total employment and solar employment
- Solar employment by occupation
- Number of additional solar jobs
- New solar job specialties
- Sources of solar funding
- Anticipated percentage change in future commercial solar sales.

The primary purpose of the screening form was to determine if an establishment was engaged in solar energy activities, and if so, to determine the type of solar energy, the number of employees and the establishment's willingness to respond to the more detailed establishment questionnaire. Basically the same screening form was also used as a follow-up to nonrespondent establishments.

The purpose of the employee form was to collect information on the following:

- Age and sex
- Years employed in solar work
- Previous and current occupation
- Hours worked per week in solar and nonsolar activities
- Type and phase of solar work
- Highest level of formal education
- Major field of study
- Special solar related skills or knowledge required in the job
- Formal training or education in solar energy
- Certification or licensing
- Relation of work to education and training
- Additional education and training needed.

Drafts of the questionnaires were prepared by Battelle and reviewed with Department of Energy personnel. Each questionnaire went through several revisions as information needs were refined.

Pretesting and Revising the Questionnaires

After the draft questionnaires were prepared, a pretest was undertaken. The pretest was aimed at verifying such factors as the following:

- That the instructions for completing the questionnaires were clear
- That the questions were understood by the respondent

- That the information or data were available
- That response categories were complete, mutually exclusive, and unambiguous
- That the time and effort required to complete the questionnaires were not excessive.

The pretest was conducted with nine solar energy establishments and nine employees engaged in solar related work. The establishments represented a wide range of size and type of organization. The establishments included large manufacturers, small manufacturers, small architectural and engineering firms, educational institutions, and R&D organizations. One employee in each establishment answered the employee questionnaire.

Personal interviews were conducted with each respondent following completion of the questionnaire. The respondent was questioned concerning any problems or difficulties experienced in completing the form. The comments did indicate the need for some additional clarifications and definitions.

The establishment respondents indicated that information concerning sales dollars was generally considered proprietary and would not be furnished. This finding required modification of the projection methodology, as well as the employer questionnaire.

Following a review of the pretest results and comments, the questionnaires were revised as appropriate. The final questionnaires and the screening form are included in Appendix A, together with the cover letters which were used.

Developing the Universe List

The universe listing of establishments was compiled from a number of sources. The primary sources are listed below.

- Battelle-Columbus, List of "Establishments Funded by ERDA" 1977.
- Battelle-Columbus, List of "Federally Funded Research and Development Centers" 1977.
- "Deskbook Directory of Solar Product Manufacturers" Solar Engineering, December 1977.

- "Education Directory, 1975-76, Colleges and Universities" Podolsky, A. and Smith, C.R., National Center for Education Statistics, U.S. Government Printing Office, Washington, D.C., 1976. - Used for addresses only.
- ERDA, List of "Active Prime Contracts in the Solar Energy Program" 1977.
- FEA, List of "Federal Energy Administration Contract Activities" 1977.
- "New Products", McPhillips, M., Solar Age, February, 1978, 42-43.
- "Informal Directory of the Organizations and People Involved in the Solar Heating of Buildings", 3rd Edition, Shurcliff, W.A., Cambridge, Mass., June, 1977.
- "Solar Age Catalog" Solar Vision, Inc., Port Jervis, N.Y., 1977.
- "Solar Collector Manufacturing Activity, July through December 1976" Federal Energy Administration, Washington, D.C., April, 1977.
- "Solar Directory" Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1975.
- "Solar Energy Directory" Centerline Corporation, Phoenix, Arizona, 1976.
- "Solar Industry Index" Solar Energy Industries Association, Washington, D.C., 1977.

Federally funded contract research centers were included, as well as R&D laboratories of Federal agencies. Other federal government agencies were omitted, but state and local government agencies were included.

The sources did not always provide information concerning the type of organization (manufacturer, installer, R&D laboratory, etc.), size of organization, nor the type of solar energy involved. Such information would have been desirable as a basis for stratification. The list was stratified by Standard Federal Region (see Figure 1), by state within region, and then alphabetically by establishment name within each state.

The universe list was carefully scanned to remove duplicate names, to correct spelling, etc. Contact names were included, if available.

A total of 2821 establishments were initially identified. Twenty-eight establishments were subsequently added during the conduct of the survey, bringing the total to 2849 establishments.

The entire list was stored on computer tape for later processing, and printing of mailing labels.

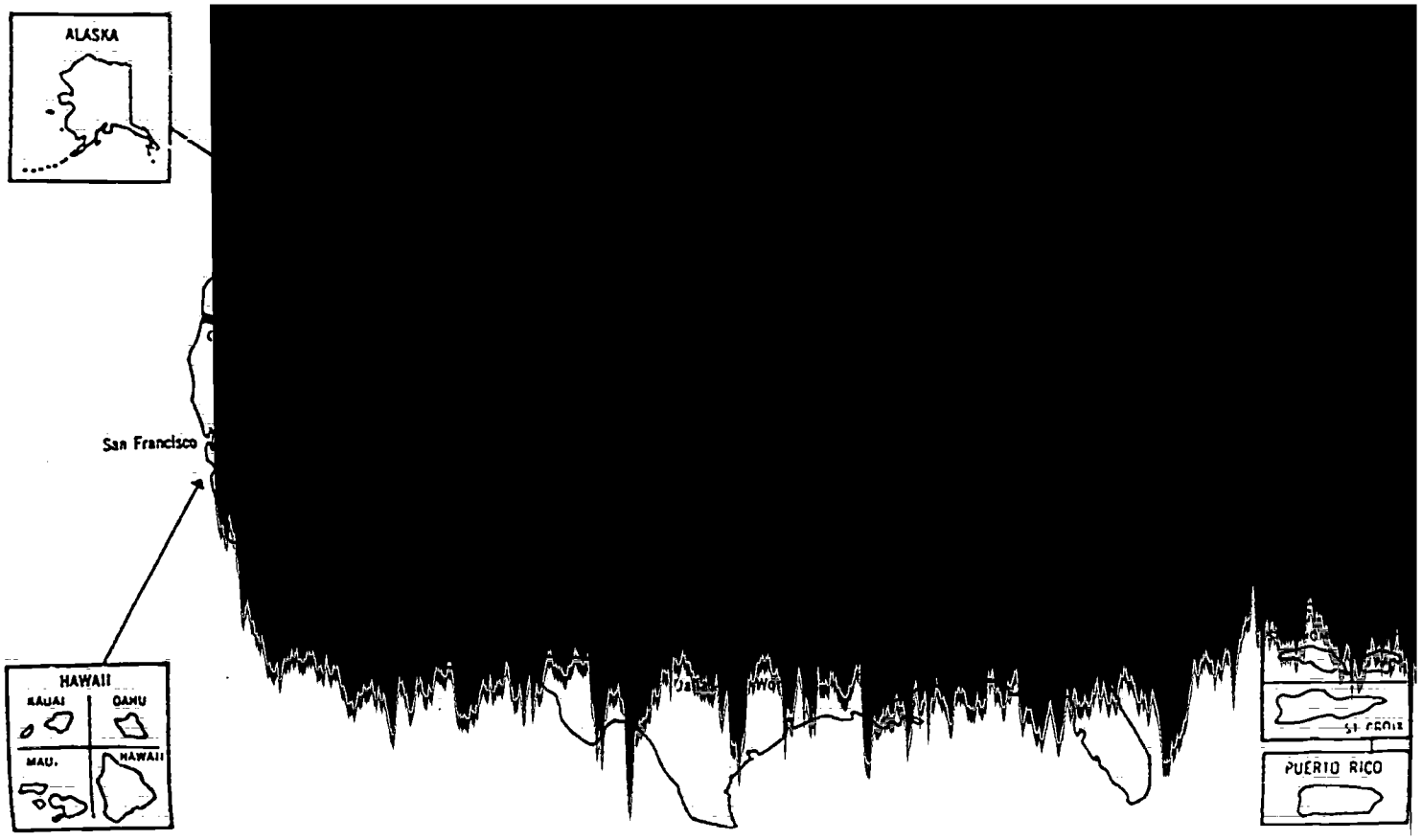


FIGURE 1. STANDARD FEDERAL REGIONS

Selecting the Sample

The universe list of establishments was divided into two groups in order to reduce costs associated with follow-up. Group 1 had extensive follow-up by mail and telephone. Group 2 received no follow-up. Group 1 consisted of a one-third systematic random sample drawn from the stratified list, obtained by choosing a random starting point and selecting every third establishment. This procedure yielded an initial sample of 940 establishments in Group 1. During the course of the survey, 28 additional establishments were identified (often by suggestions from respondents or from new sources), and these establishments were added to Group 1 (to speed up contact procedures) to bring the total number of establishments in the Group 1 sample to 968. The remaining 1881 establishments were designated as Group 2.

Employees working in solar energy were sampled within each respondent organization. The selection was made by the establishment following instructions furnished by Battelle (see Instructions for Distribution of Materials in Appendix A). The sample size was based on the total number of solar employees reported by the establishment. Table 1 presents the plan for sample size selection. A sample of approximately ten percent of employees engaged in solar work was requested, with a minimum of one and a maximum of ten employees. Few establishments had as many as 100 solar energy employees.

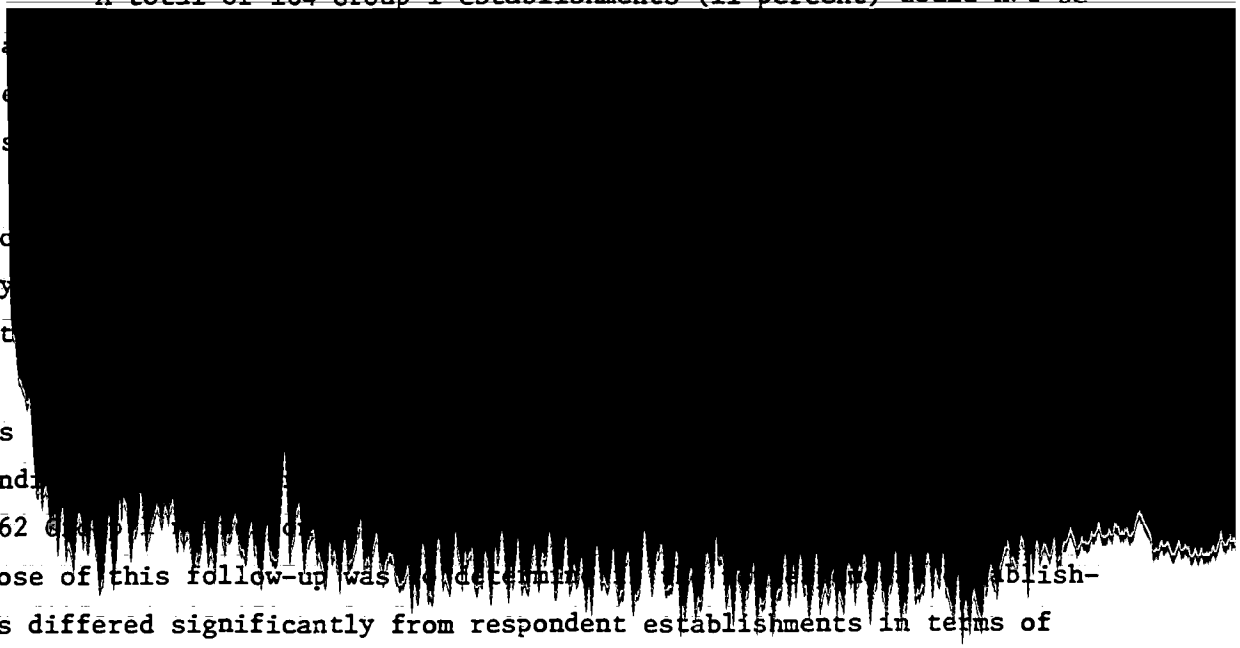
Conducting the Survey

The Group 1 and Group 2 establishment samples were treated differently during the conduct of the survey. Group 1 establishments were mailed the employer questionnaire together with copies of the cover letters from the Department of Energy and the Solar Energy Industries Association (see Appendix A). Mail returned as undeliverable was checked, and a directory search was initiated for a correct or better address. Then, the questionnaire and cover letters were resent.

TABLE 1. SAMPLING PLAN FOR EMPLOYEE SELECTION, 1978

Number of Solar Energy Employees in Establishment	Sample Size
1-14	1
15-24	2
25-34	3
35-44	4
45-54	5
55-64	6
65-74	7
75-84	8
85-94	9
95 and above	10

A total of 104 Group 1 establishments (11 percent) could not be



of 162 [illegible] purpose of this follow-up was [illegible] establishments differed significantly from respondent establishments in terms of geographic region, type of establishment, whether they were engaged in solar energy work, type of solar energy work engaged in, total number of employees and number of employees working in solar. The establishments contacted were those in Group 1 where three mail contacts had already been attempted. A total of 91 establishments were contacted by telephone. Those not contacted either had gone out of business or had no telephone listing.

When Group 1 employer questionnaires were returned, the appropriate number of employee questionnaires to be sent was determined, based on the number of employees engaged in solar energy work (see Table 1). The package of employee forms, cover letters, and return envelopes was sent to the contact person at each responding establishment. This person was asked to distribute the employee questionnaires to a random sample of employees working in solar energy. To obtain a random sample, the contact person was requested to list the names of the establishment's solar energy employees alphabetically, or use an already existing listing (such as a payroll list). The ordinal positions on the list to be given employee forms were randomly selected by Battelle and sent to the employer. It is not known how reliably this procedure was followed by the establishments.

It should be noted that other than an establishment code number, the employee questionnaires had no identifying information This, plus direct return of the forms to Battelle, ensured confidentiality of the employee responses.

Group 2 establishments were mailed the short screening form. Respondents who indicated they would be willing to complete the more detailed questionnaire were sent employer questionnaires, and the appropriate number of employee forms. (The screening form provided the information necessary to determine the number of employee questionnaires to send.) No further attempts were made to contact respondents and nonrespondents in Group 2.

RESULTS

A total of 1314 establishment responses were received, representing 46 percent of the establishments in the sampling frame, and 51 percent of the establishments contacted. Of the 1314 establishments, 285 (22 percent) reported they were not engaged in any type of solar work. A total of 466 establishments (35 percent) completed only the short screening form, and 563 establishments (43 percent) completed the long employer questionnaire. Some respondents did not answer every question in the employer questionnaire. An analysis of the response rate is presented in Appendix B.

An estimate of the number of establishments in the sampling frame engaged in solar energy work as derived (see Appendix B). The two-standard error estimate of the number of establishments engaged in solar energy work in 1978 was 1867 ± 65. This estimate was used to compute the estimated total employment in solar energy in subsequent analyses.

Respondent establishments were compared to the sample of 91 nonrespondents in terms of type of organization, geographic location, type of solar energy, total employment, and solar employment. In general, the results of these analyses were negative, indicating little or no difference between respondent and nonrespondent establishments.

A comparison of Group 1 and Group 2 respondent establishments disclosed no reliable differences between the two groups in terms of type of organization, geographic location, industrial classification, primary type of solar energy that organization was involved in, number of different types of solar energy, percent solar R&D work, total employment, solar employment, percent solar employment, and type of solar work. Thus, the method of contact and extent of follow-up did not make a difference in the kind or size of responding establishments. Based on these findings, the two groups were combined in subsequent analyses.

The analyses of possible nonresponse bias are described more fully in Appendix B.

The study results are presented below in seven sections: Description of Establishments, Solar Employment in Establishments, Occupations and Skills Required, Characteristics of Solar Employees, Hours Worked by Employees, Education and Training Needs of Employees, and Employment Projections. Additional tables of results are presented in Appendix C.

Description of Establishments

A total of 563 employer questionnaires were received from establishments engaged in solar activities. The geographic distribution of establishments is shown in Table 2. The five states with the most solar establishments were California (16 percent of total respondents), New York (8 percent), Massachusetts (7 percent), Colorado (4 percent), and Texas (4 percent).

Table 3 presents the distribution of respondents in terms of type of organization. Most establishments were categorized as private industries or businesses. Federal government organizations included only Federal laboratories engaged in solar or solar related energy work. Federally financed Contract Research Centers were included with nonprofit organizations. Public Utilities included public or privately-owned gas and/or electric companies, but not telephone companies.

Table 4 presents the primary activities (Standard Industrial Classification) of the overall organization of the responding establishments. Establishments engaged in solar energy work represented many different industrial sectors. Approximately 40 percent of the establishments came from the service sector, and approximately 30 percent came from the durable goods manufacturing sector.

Table 5 presents the percentage of establishments working with different types of solar energy technologies and applications. Since respondents could indicate as many types as appropriate, the percentages in the first column of Table 5 exceed 100 percent. Nearly 83 percent of the establishments were engaged in some form of work with solar space heating and cooling. Eighty percent were engaged in work related to solar water heating. Seventy-two percent of the establishments were involved in work in both space heating and cooling and water heating. For this reason, these two types were often combined in the analyses that follow.

TABLE 2. GEOGRAPHICAL REGION OF RESPONDENT ESTABLISHMENTS, 1978

Federal Region	Percent of Respondents (N=563)
I	13.7
II	11.2
III	12.6
IV	9.2
V	12.8
VI	7.3
VII	3.6
VIII	6.2
IX	20.4
X	3.0

TABLE 3. TYPE OF ORGANIZATIONS ENGAGED IN SOLAR ACTIVITIES, 1978

Type of Organization	Percent of Respondents (N=558)
Private Industry	61.1
Construction Contractor	8.2
Public Utility	6.6
Federal Government	1.6
State or Local Government	5.9
Nonprofit Organization	7.0
Educational Institution	8.6
Other	0.9

TABLE 4. INDUSTRIAL CLASSIFICATION OF ESTABLISHMENTS, 1978

Industry	Standard Industrial Classification Code	Percent of Respondents (N=555)
Durable Goods Manufacturing		29.3
Lumber and Wood Products	24	0.5
Stone, Clay and Glass Products	32	1.1
Primary Metal Industries	33	1.1
Fabricated Metal Products	34	6.8
Machinery, Except Electrical	35	1.3
Electric and Electronic Equipment	36	4.7
Transportation Equipment	37	0.4
Instruments and Related Products	38	1.3
Miscellaneous Manufacturing	39	2.2
Solar Products*	--	9.9
Construction		8.3
General Building Contractors	15	4.3
Special Trade Contractors	17	4.0
Nondurable Goods Manufacturing		2.8
Food and Kindred Products	20	0.2
Apparel and Other Textiles	23	0.2
Chemicals and Allied Products	28	0.9
Petroleum and Coal Products	29	0.4
Rubber and Plastic Products	30	1.1
Mining	10-14	0.2
Transportation and Public Utilities	40-49	7.6
Wholesale or Retail Trade	50-59	6.3
Finance, Insurance and Real Estate	60-67	0.2
Services		40.7
Personal Services	72	0.2
Business Services	73	0.5
Educational Services	82	10.8
Engineering and Architectural Services	891	16.8
Research Services	7391, 892	9.7
Other Services	--	2.7
Public Administration	91-97	4.9

*Fifty-five establishments identified their primary activity as the manufacturing of solar products.

TABLE 5. TYPE OF SOLAR ENERGY TECHNOLOGY, 1978

Type of Solar Energy	Percentage of Respondents Engaged in Each Type* (N=549)	Percentage of Respondents Primarily Engaged in Each Type (N=482)
Space Heating and Cooling	82.7	48.3
Water Heating	80.1	28.6
Industrial Process Heat	37.5	1.9
Thermal Power	18.8	2.7
Ocean Thermal Conversion	9.5	2.7
Photovoltaic Conversion	26.6	6.2
Wind Conversion	24.8	3.1
Biomass Conversion	17.9	2.7
Other	8.4	3.7

* The sum of the percentages exceeds 100 since respondents could check all types that apply.

Not shown in the table is the percentage of establishments indicating work in more than one type of solar energy. Seventeen percent of the establishments indicated they were working in only one type of solar energy. Twenty-nine percent indicated two types, and twenty-five percent indicated three types. Twenty-nine percent of the establishments indicated four or more types. It is clear that many solar establishments were working with many different types of solar energy, rather than specializing at this time.

Establishments also indicated the one type of solar energy in which the greatest number of employees worked. The results are shown in the second column of Table 5. Nearly half the respondents were primarily engaged in work related to solar space heating and cooling.

Table 6 presents a classification of the type of solar work engaged in by the respondents. This classification was based on the principal solar products and services provided by the establishment and its standard industrial classification. More establishments were engaged in providing R&D services than any other category of work. The percentage of respondents providing different solar-related products or services is presented in Appendix Table C-1.

Crosstabulations of type of organization by primary type of solar energy and type of solar work are presented in Appendix Tables C-2 and C-3. Crosstabulations of type of industry by primary type of solar energy and type of solar work are presented in Appendix Tables C-4 and C-5.

Table 7 shows the type of work involved for each type of solar energy. Space heating and cooling and water heating involved a wide variety of different types of work. For other types of solar energy, the largest percentage of establishments were providing R&D services, reflecting the fact that these types were not as commercialized as space heating and cooling and water heating.

Table 8 presents the distribution of respondents in terms of the percentage of solar work in research and development activities. Over 30 percent of the establishments had over 95 percent of their solar work in R&D. Another 30 percent had less than 15 percent of their solar work in R&D. The overall average percent solar work in R&D was 49 percent. As shown in Table 9, most construction contractors and private industrial

TABLE 6. TYPE OF SOLAR ENERGY WORK, 1978

Type of Solar Energy Work	Percent of Respondents (N=546)
Manufacturing, flat plate collectors	13.4
Manufacturing, other products	17.4
Installation	12.3
R&D Services	22.7
Architectural and Engineering Services	18.1
Other Services	16.1

TABLE 7. TYPE OF SOLAR ENERGY WORK BY PRIMARY TYPE OF SOLAR ENERGY, 1978

Type of Solar Work	Primary Type of Solar Energy: Space Heating and Cooling N	%	Water Heating N	%	Industrial Process Heat N	%	Thermal Power N	%	Ocean Thermal Conversion N	%	Photovoltaic Conversion N	%	Wind Conversion N	%	Biomass Conversion N	%	Other N	%
Manufacturing, flat plate collectors	30	13.1	33	24.4	1	11.1	1	8.3	0	0.0	3	10.3	1	7.1	0	0.0	0	0.0
Manufacturing, other products	28	12.2	21	15.6	2	22.2	4	33.3	1	7.7	11	37.9	5	35.7	2	15.4	6	33.3
Installation	27	11.8	29	21.5	1	11.1	1	8.3	0	0.0	1	3.4	0	0.0	1	7.7	1	5.6
R&D Services	47	20.5	14	10.4	4	44.4	5	41.7	7	53.8	12	41.4	8	57.1	8	61.5	5	27.8
Architectural and Engineering Services	62	27.1	14	10.4	1	11.1	1	8.3	5	38.5	1	3.4	0	0.0	1	7.7	1	5.6
Other Services	35	15.3	24	17.8	0	0.0	0	0.0	0	0.0	1	3.4	0	0.0	1	7.7	5	27.8
Total	229	100.0	135	100.0	9	100.0	12	100.0	13	100.0	29	100.0	14	100.0	13	100.0	18	100.0

TABLE 8. PERCENTAGE OF SOLAR WORK IN RESEARCH AND DEVELOPMENT, 1978

Percent Solar R&D Work	Percent of Respondents (N=544)
0- 4.9	13.6
5- 14.9	17.3
15- 24.9	10.3
25- 34.9	7.7
35- 44.9	2.2
45- 54.9	8.1
55- 64.9	1.1
65- 74.9	1.5
75- 84.9	3.9
80- 94.9	3.7
95-100	30.7

TABLE 9. PERCENTAGE OF SOLAR WORK IN R&D BY TYPE OF ORGANIZATION, 1978

Percent Solar R&D Work	Type of Organization															
	Private Industry		Construction Contractor		Public Utility		Federal Government		State or Local Government		Nonprofit Organization		Educational Institution		Other	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
10% or less	132	39.4	24	53.3	2	5.6	1	11.1	5	17.9	2	5.4	0	0.0	1	33.3
11% to 49%	89	26.6	13	28.9	3	8.3	0	0.0	3	10.7	2	5.4	1	2.1	0	0.0
50% to 89%	54	16.1	7	15.6	6	16.7	2	22.2	3	10.7	6	16.2	1	2.1	2	66.7
90% or more	60	17.9	1	2.2	25	69.4	6	66.7	6	60.7	27	73.0	46	95.8	0	0.0
Total	335	100.0	45	100.0	36	100.0	9	100.0	28	100.0	37	100.0	48	100.0	3	100.0

establishments performed a low percentage of their solar work in R&D. Public utilities, governmental agencies, nonprofit organizations and educational institutions tended to perform a high percentage of their solar work in R&D. Crosstabulations of percentage of solar work in R&D by type of industry, primary type of solar energy and type of solar work are presented in Appendix Tables C-6 through C-8.

Table 10 presents the source of funds used to finance solar activities. The three types of solar energy which were funded over 50 percent from commercial sources were space heating and cooling, water heating, and industrial process heat. The only type which was funded over 50 percent from federal R&D sources was ocean thermal conversion.

Establishments with commercial sales were asked to estimate the percentage change in commercial solar sales between the base year of 1978 and 1979, 1981, and 1983. The results are presented in Table 11. The majority of respondents (upwards of 85 percent) anticipated increased commercial solar sales. A small percentage of respondents anticipated no change, and an even smaller percentage anticipated a decrease. The overall average percent change anticipated in 1979 (including both increases and decreases) was +81.7 percent. The overall average percent change anticipated in 1981 was +134.0 percent, and the overall average percent change anticipated in 1983 was +193.5 percent. It should be noted that these estimates were not used to develop future solar employment projections, although they agree closely with the commercial projections.

Solar Employment in Establishments

The total employment reported by the respondent establishments was 485,162 with a mean of 885 employees per establishment and a standard deviation of 2337.2. Total reported solar employment was 6,257 with a mean of 12 solar employees per establishment and a standard deviation of 23.3. Table 12 presents the distribution of total employment among respondents. Note should be taken of the large number of very small establishments engaged

TABLE 10. AVERAGE PERCENT OF SUPPORT RECEIVED FROM DIFFERENT SOURCES FOR FINANCING SOLAR ACTIVITIES BY TYPE OF SOLAR ENERGY, 1978

Types of Solar Energy	Source					Number of Respondents
	Research and Development Funded by Federal Government	Research and Development Funded by Other Sources	Commercial Solar Activities Funded Internally	Other	Total	
Space Heating and Cooling	23.3	17.0	51.1	8.6	100.0	399
Water Heating	18.1	17.0	56.1	8.8	100.0	354
Industrial Process Heat	20.7	19.1	51.6	8.7	100.0	153
Thermal Power	38.6	25.6	23.1	12.8	100.0	89
Ocean Thermal Conversion	60.1	21.9	11.3	6.7	100.0	47
Photovoltaic Conversion	36.4	21.0	30.7	12.0	100.0	123
Wind Conversion	28.9	33.3	26.5	11.3	100.0	107
Biomass Conversion	38.8	26.7	20.7	13.8	100.0	77
Other	20.2	17.5	45.2	17.1	100.0	61

TABLE 11. ANTICIPATED CHANGE IN COMMERCIAL SOLAR SALES, 1978

Year	Direction of Change	Number of Respondents	Percent of Respondents	Average Perc Change Antici (Relative to
1979	Increase	263	85.1	+98.3
	No Change	37	12.0	0.0
	Decrease	9	2.9	-68.3
1981	Increase	267	89.0	+151.5
	No Change	28	9.3	0.0
	Decrease	5	1.7	-51.0
1983	Increase	253	86.9	+223.7
	No Change	34	11.7	0.0
	Decrease	4	1.4	-72.5

TABLE 12. ESTABLISHMENT SIZE, 1978

Total Employment	Percent of Respondents (N=548)
1 - 2	9.3
3 - 5	12.6
6 - 10	15.3
11 - 20	13.0
21 - 40	9.7
41 - 100	11.5
101 - 400	9.1
401 - 3000	10.2
Greater than 3000	9.3

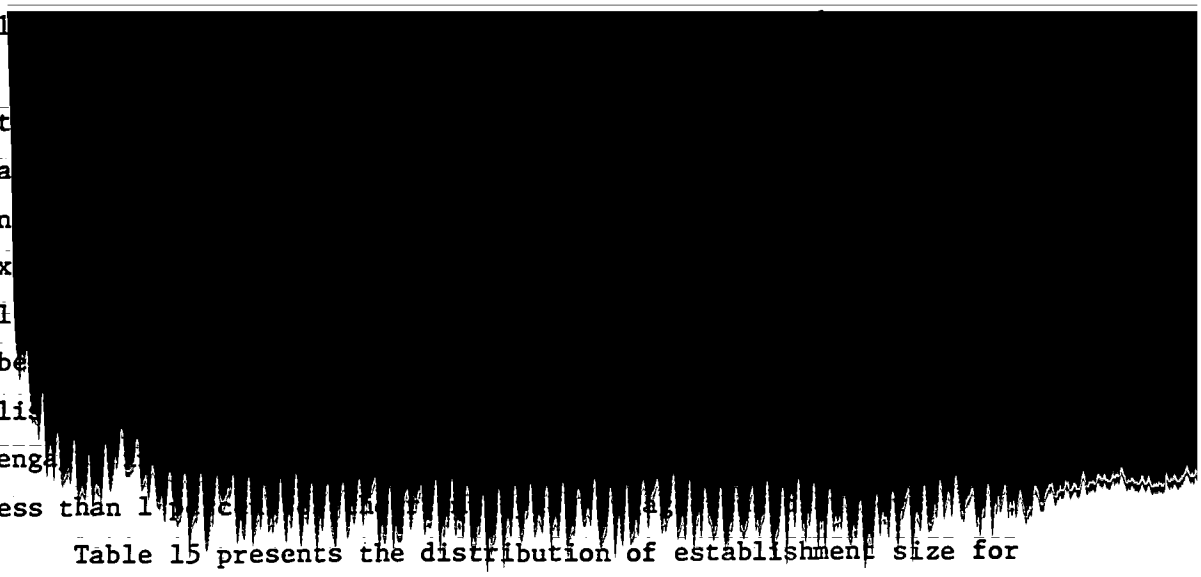


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Table 15 presents the distribution of establishment size for each type of solar work. Installation, architectural and engineering services, and other services were performed mainly by small establishments (10 or fewer employees), whereas R&D services were performed mainly by large establishments (more than 400 employees). Manufacturing work was performed by both large and small establishments.

Table 16 presents the relationship between percentage of solar work in R&D and size of establishment. Small establishments tended to perform only a small percentage of their solar work in R&D activities, whereas large establishments performed most of their solar work in R&D. Further analysis of the data in Table 16 showed that approximately 75 percent of the solar work in large establishments was R&D work.

Crosstabulations of establishment size by primary type of solar energy are presented in Appendix Table C-9. Crosstabulations of percentage solar employment by type of organization, type of industry, primary type of solar energy, type of solar work, and percentage of solar work in R&D are presented in Appendix Tables C-10 through C-14.

The estimated number of persons working in solar in 1978 was 22,500. This figure represents all employees both full and part-time, direct and support, working in solar. This estimate was based on solar employment data supplied by the 518 establishments which answered the occupational distribution question. These 518 establishments represented 27.75 percent (± 1.0 percent) of the 1867 establishments (± 65 establishments)

TABLE 13. PERCENT SOLAR EMPLOYMENT, 1978

Percent Solar Employment	Percent of Respondents (N=541)
Less than 4%	26.8
5% - 24%	22.2
25% - 49%	10.0
50% - 99%	12.2
100%	28.8

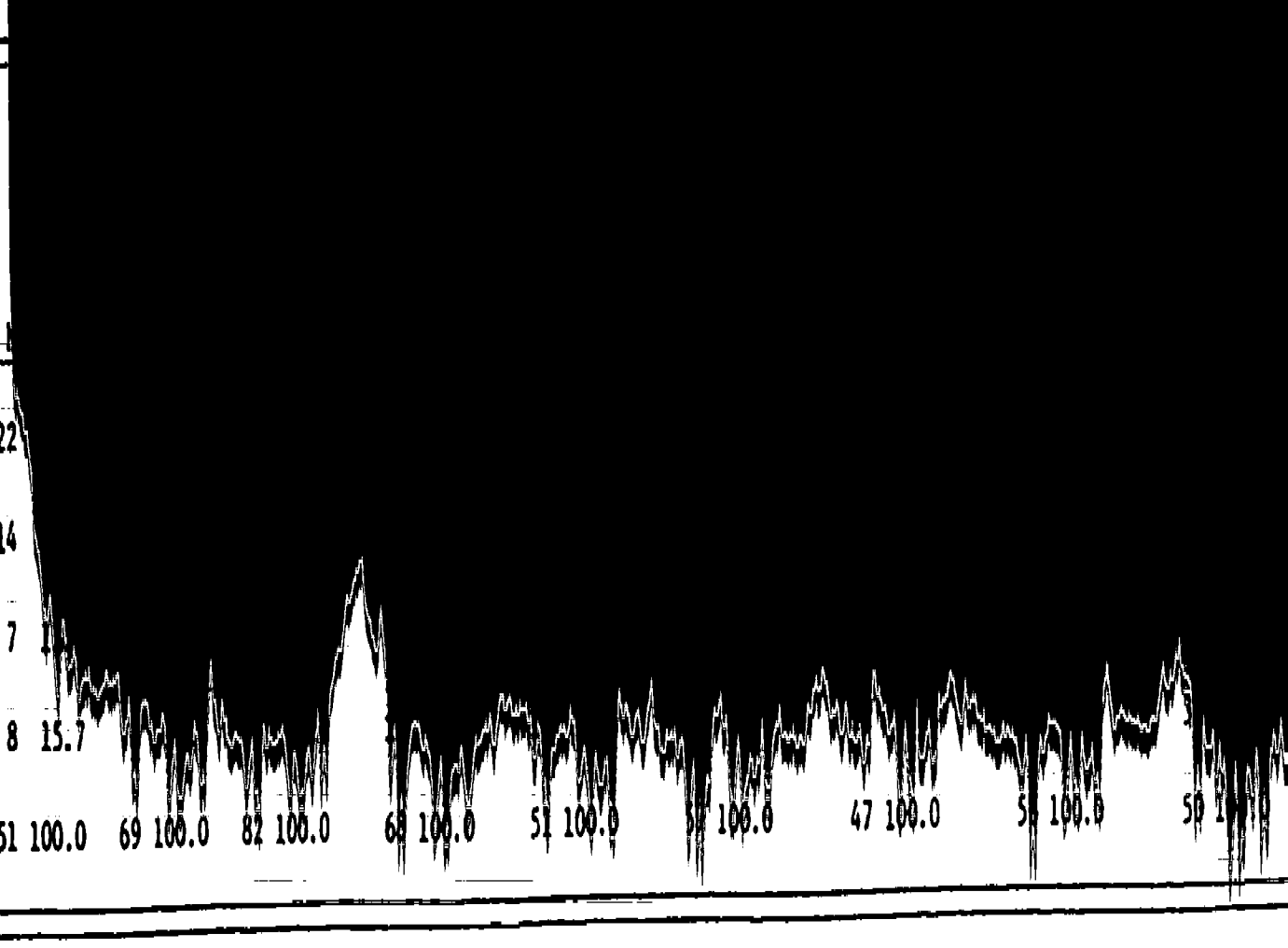
TABLE 14. PERCENTAGE SOLAR EMPLOYMENT BY ESTABLISHMENT SIZE, 1978

Percent Solar Employment	Total Employment																			
	1-2		3-5		6-10		11-20		21-40		41-100		101-400		401-3000		Gr t 3	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	
Less than 4%	0	0.0	0	0.0	0	0.0	0	0.0	3	5.8	10	16.1	30	61.2	51	92.7	51	1
5% to 24%	0	0.0	1	1.5	5	6.0	25	35.7	32	61.5	37	59.7	16	32.7	4	7.3	0	
25% to 49%	0	0.0	7	10.3	12	14.5	16	22.9	12	23.1	6	9.7	1	2.0	0	0.0	0	0.
50% to 99%	5	9.8	14	20.6	26	31.3	13	18.6	2	3.8	5	8.1	1	2.0	0	0.0	0	0.
100%	46	90.2	46	67.6	40	48.2	16	22.9	3	5.8	4	6.5	1	2.0	0	0.0	0	0.
Total	51	100.0	68	100.0	83	100.0	70	100.0	52	100.0	62	11.5	49	100.0	55	100.0	51	100.

TABLE 15. ESTABLISHMENT SIZE BY TYPE OF SOLAR WORK, 1978

	Type of Solar Work									
	Manufacturing Flat Plate Collectors		Manufacturing Other Products		Installation		R&D Services		[redacted]		Other Services	
Total Employment	N	%	N	%	N	%	N	%			N	%
1 - 2	7	9.7	3	3.3	8	11.9	5	4.2			14	16.1
3 - 5	11	15.3	11	12.1	11	16.4	6	5.0			11	12.6
6 - 10	20	27.8	13	14.3	19	28.4	4	3.3			13	14.9
11 - 20	10	13.9	12	13.2	11	16.4	13	10.8			10	11.5
21 - 40	6	8.3	6	6.6	7	10.4	10	8.3	10	10.4	12	13.8
41 - 100	2	2.8	14	15.4	6	9.0	15	12.5	12	12.5	12	13.8
101 - 400	9	12.5	10	11.0	2	3.0	16	13.3	8	8.3	3	3.4
401 - 3000	2	2.8	11	12.1	2	3.0	30	25.0	5	5.2	5	5.7
Greater than 3000	5	6.9	11	12.1	1	1.5	21	17.5	3	3.1	7	8.0
Total	72	100.0	91	100.0	67	100.0	120	100.0	96	100.0	87	100.0

Percent Solar R&D Work										
10% or Less	22									
11% to 49%	14									
50% to 89%	7									
90% or more	8	15.7								
Total	51	100.0	69	100.0	82	100.0	68	100.0	51	100.0



estimated to have been engaged in solar energy activities in 1978. To obtain the estimated number of persons working in solar, the reported number of solar employees was divided by .2775 and rounded to the nearest 100 employees. The 95 percent confidence interval (two standard errors) of this estimate is approximately ± 3.5 percent (± 800 persons).

Occupations and Skills Required

The occupational distribution of solar employment is shown in Table 17 for R&D activities, commercial activities (excluding installation), and installation activities. The reported number of employees is presented for the more frequently mentioned occupations, based on 518 establishments which answered the occupational distribution question. Data on the less frequently mentioned occupations are presented in Appendix Table C-15. The large number of "other" within each occupational group (in Appendix Table C-15) indicates that employers had difficulty specifying more than the general occupational group for many employees. For example, employers could not identify the specific occupation for one-third of their engineers, 40 percent of the scientists, one-half of the technicians and 55 percent of their skilled craft and operative employees. Generally, job classifications used in industry bear an imperfect relationship to occupational fields.

As shown in Table 17, mechanical engineers were the most frequently reported occupation. Engineers made up the largest occupational group in R&D activities. Skilled craft and operative workers and unskilled workers made up the largest occupational groups in commercial activities (excluding installation), and skilled craft and operative workers made up the largest occupational group in installation activities. The specific occupations involved in installation included mechanical engineers; plumbers and pipe fitters; carpenters; heating, ventilating and air conditioning workers; and sheet metal workers and tinsmiths.

TABLE 17. OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT IN SOLAR ACTIVITIES, REPORTED AND ESTIMATED NUMBERS AND PERCENTAGES, 1978. BASED ON 518 REPORTING ESTABLISHMENTS

Occupation	Research and Development			Commercial (except Installation)			Installatio			Total		
	Reported N	%[a]	Estimated N[c]	Reported N	%[a]	Estimated N[c]	Reported N	%[a]			%[a]	Estimated N[c]
Engineers	1398	40	5,200	440	18	1,600	55	15			30	6,900
Agricultural	28	1		2	b		0	-			b	
Chemical	54	2		28	1		0	-			1	
Civil	26	1		4	b		1	b			b	
Electrical/Electronic	244	7		35	1		5	1			5	
Mechanical	509	15		181	7		31	9			12	
Metallurgical/Materials	55	2		5	b		2	1			1	
Other	482	14		185	8		16	4			11	
Scientists	469	13	1,700	54	2	200	6	2			8	1,900
Biologists	20	1		1	b		0	-			b	
Chemists	35	1		8	b		1	b			1	
Computer Specialists	48	1		6	b		2	1			1	
Physicists	117	3		18	1		3	1			2	
Other	249	7		21	1		0	-			4	
Other Professionals	482	14	1,800	356	15	1,300	37	10			14	3,200
Architects	71	2		115	5		6	2			3	
College/University Teachers	37	1		3	b		0	-			1	
Economists	26	1		4	b		3	1			1	
Managers/Administrators	127	4		60	2		11	3			3	
Marketing Specialists	23	1		67	3		11	3			2	
Operations/Systems Researchers	22	1		9	b		2	1			1	
Other	176	5		98	4		4	1			4	
Technicians	494	14	1,800	176	7	600	21	6	100		11	2,500
Chemical	21	1		2	b		0	-			b	
Electrical/Electronic	112	3		23	1		3	1			2	
Mechanical	98	3		46	2		10	3			2	
Other	263	8		105	4		8	2			6	
Skilled Crafts and Operatives	238	7	900	649	27	2,400	170	47	600	1057	17	3,900
Carpenters	9	b		10	b		27	7		43	1	
HVAC Workers	8	b		18	1		22	6		48	1	
Machinists	12	b		14	1		3	1		29	b	
Mechanics	26	1		13	1		4	1		43	1	
Plumbers/Pipe Fitters	5	b		37	2		42	12		84	1	
Sheetmetal Workers /Tinsmiths	9	b		28	1		17	5		54	1	
Welders/Flame-Cutters	12	b		11	b		6	2		29	b	
Others	157	5		518	21		52	14		727	12	
Clerical and Unskilled	315	9	1,200	717	30	2,600	70	19	300	1102	18	4,000
No Occupation Given	86	2	-	24	1	-	0	-	-	110	2	-
Total, All Occupations	3482	100	12,500	2416	100	8,700	359	100	1,300	6257	100	22,500

a Detail may not add to subtotal due to rounding/Total may not add to 100% due to rounding.

b Less than 0.5%.

c Includes allocation of "No Occupation Given" category/Detail may not add to total due to rounding.

d Less than 50.

Overall, the number of employees working in solar R&D was greater than the number working in solar commercial and installation activities combined. This finding points up an important characteristic of employment in the solar energy area - a large percentage of employment was in R&D work.

Further examination of Table 17 discloses that the percentage of "other professionals" remained fairly constant (between 10 percent and 15 percent) in research and development activities, commercial activities and installation activities, whereas the percentages of the other occupational groups fluctuated among the different activities. The reported occupational distributions appeared to reflect the type of work currently performed in the different activities. Thus, commercial activities, which include manufacturing, involved large numbers of engineers, machine operatives and unskilled workers. In the future, the mix of occupations is likely to change as different solar technologies become commercialized, and as more standardization and automation occur in manufacturing and installation activities.

Table 18 presents the reported and estimated number of solar employees by each type of solar energy. Most employees (65 percent) were working in establishments primarily engaged in space heating and cooling/water heating. Establishments primarily engaged in space heating and cooling/water heating reported more employees in commercial activities than in R&D activities. This finding reflects the level of commercialization of solar space heating and solar water heating. As these technologies become more commercialized, employment will, of course, shift to commercial activities. In addition, the occupational mix will change. Occupational distributions of solar employment for establishments primarily engaged in space heating and cooling/water heating, industrial process heat, photovoltaic conversion, and all other types of solar energy combined are presented in Appendix Tables C-16 through C-19.

Since large and small employers could have different jobs available, a comparison of the occupational distributions of relatively larger employers in the solar energy field (those with more than 40 total employees) and smaller employers (those with 40 or fewer employees)

TABLE 18. REPORTED AND ESTIMATED EMPLOYMENT IN DIFFERENT TYPES OF SOLAR ENERGY, 1978

Type of Solar Energy	Number of Establishments Primarily Engaged in that Type	Research and Development			Commercial (Including Installation)			Total		
		Reported		Estimated	Reported		Estimated	Reported		Estimated
		N	%[a]	N[b]	N	%[a]	N[b]	N	%[a]	N[b]
Space heating & cooling/ water heating	346	1,576	45.3	6,800	2,022	72.9	7,900	3,598	57.5	14,700
Industrial process heat	8	41	1.2	200	25	0.9	100	66	1.1	300
Thermal power	12	143	4.1	600	5	0.1	d	148	2.4	600
Ocean thermal conversion	13	101	2.9	400	2	c	d	103	1.6	400
Photovoltaic conversion	28	639	18.4	2,700	427	15.4	1,700	1,066	17.0	4,400
Wind conversion	15	231	6.6	1,000	61	2.2	200	292	4.7	1,200
Biomass conversion	12	188	5.4	800	11	0.4	d	199	3.2	800
Other	16	59	1.7	-	75	2.7	-	134	2.1	-
Missing	68	504	14.5	-	147	5.3	-	651	10.4	-
Total	518	3,482	100.0	12,500	2,775	100.0	10,000	6,257	100.0	22,500

a Total may not add to 100% due to rounding.

b Includes allocation of "Missing" and "Other" Categories/Detail may not add to total due to rounding.

c Less than 0.05%.

d Less than 50.

was made. Only establishments primarily involved in space heating and cooling or water heating were included in this comparison. (The other types of solar energy were represented by too few establishments.) Table 19 presents the comparison. The major difference in the distributions was that large employers had a lower percentage of employees in the other professional group. This difference may reflect an economy of scale, in that management and administrative personnel are required regardless of organizational size, but proportionally fewer are required in large organizations. The difference could also be due to the predominant R&D nature of the work of large establishments.

Table 20 presents the occupations reported as difficult to hire. Engineers were most often reported as difficult to hire, followed by "other professionals." Since the occupations differed in frequency with which they were reported, a direct comparison among occupations required adjusting the frequency of report-of-difficult-to-hire by the frequency of report-of-occupation. A difficulty ratio was computed by dividing the frequency of report-of-difficult-to-hire by the frequency of report-of-occupation. A ratio of 1.000 would mean that every time the occupation was reported, it was also reported as difficult to hire. Using the difficulty ratio, the occupations for which the establishments were having the most difficulty in hiring were atmospheric scientists, operations/systems researchers, and college/university teachers. Difficulty tended to be low among skilled craft and operative jobs, and among clerical and unskilled jobs. Apparently, employers were not having much difficulty finding suitably skilled persons in these occupational groups.

Tables 17 and 20, taken together, suggest that the required skill level for many jobs in solar is low and that employees in these jobs do not need a great deal of special training in solar energy to perform their work. This is partly due to the inclusion of support personnel (clerical, administrative) in the employment data which was collected. Nevertheless, many of the direct personnel fall into semi-skilled and unskilled labor categories. These jobs generally require little or no special training prior to employment and require a minimum of on-the-job training. The supply of manpower to fill these categories

TABLE 19. OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT FOR LARGE AND SMALL EMPLOYERS ENGAGED IN SOLAR SPACE HEATING AND COOLING/WATER HEATING, 1978. BASED ON 117 LARGE EMPLOYERS (GREATER THAN 40 EMPLOYEES) AND 225 SMALL EMPLOYERS (40 OR FEWER EMPLOYEES)

	Research and Development		Commercial		Total	
Large Employers Occupational Group	Reported N	%	Reported N	%	Reported N	%
Engineers	508	44.7	180	18.8	688	32.9
Scientists	127	11.2	13	1.4	140	6.7
Other Professionals	150	13.2	96	10.0	246	11.7
Technicians	120	10.6	69	7.2	189	9.0
Skilled Crafts and Operatives	70	6.2	212	22.1	282	13.5
Clerical and Unskilled Workers	122	10.7	374	39.0	496	23.7
No Occupation Given	39	3.4	14	1.5	53	2.5
Total, All Groups	1,136	100.0	958	100.0	2,094	100.0
Small Employers Occupational Group						
Engineers	148	34.5	150	15.7	298	21.5
Scientists	33	7.7	18	1.9	51	3.7
Other Professionals	109	25.4	191	20.0	300	21.7
Technicians	44	10.3	85	8.9	129	9.3
Skilled Crafts and Operatives	45	10.5	286	29.9	331	23.9
Clerical and Unskilled Workers	37	8.6	218	22.8	255	18.4
No Occupation Given	13	3.0	8	.8	21	1.5
Total, All Groups	429	100.0	956	100.0	1,385	100.0

TABLE 20. DIFFICULT TO HIRE OCCUPATIONS, 1978.
BASED ON 518 REPORTING ESTABLISHMENTS

Occupation	Reported Frequency of Difficult to Hire	Percent of Reports*	Difficulty Ratio
Engineers	130	41.4	.239
Agricultural	3	1.0	.300
Architectural	4	1.3	.286
Chemical	4	1.3	.143
Civil	3	1.0	.200
Electrical/Electronic	16	5.1	.200
Mechanical	50	15.9	.256
Metallurgical/Materials	3	1.0	.111
Other	47	15.0	.270
Scientists	32	10.2	.168
Atmospheric	4	1.3	.571
Biologists	0	0.0	.000
Chemists	3	1.0	.120
Computer Specialists	7	2.2	.194
Physicists	4	1.3	.118
Other	14	4.5	.189
Other Professionals	67	21.3	.170
Architects	16	5.1	.222
College/University Teachers	5	1.6	.357
Economists	2	0.6	.077
Managers/Administrators	15	4.8	.136
Marketing Specialists	13	4.1	.260
Operations/Systems Researchers	6	1.9	.545
Other	10	3.2	.090
Technicians	38	12.1	.175
Chemical	1	0.3	.125
Draftsmen	5	1.6	.294
Electrical/Electronic	7	2.2	.184
Mechanical	9	2.9	.150
Other	16	5.1	.170
Skilled Crafts and Operatives	39	12.4	.142
Carpenters	1	0.3	.042
HVAC Workers	3	1.0	.158
Machinists	1	0.3	.071
Mechanics	3	1.0	.176
Plumbers/Pipe Fitters	5	1.6	.143
Sheetmetal Workers/Tinsmiths	4	1.3	.182
Welders/Flame Cutters	2	0.6	.154
Others	20	6.4	.154
Clerical and Unskilled	2	0.6	.011
No Occupation Given	6	1.9	.375
Total, all occupations	314	100.0	.173

*Detail may not add to subtotal due to rounding/Total may not add to 100 percent due to rounding.

is therefore more elastic. Thus, employers have little difficulty hiring for these occupational groups.

Table 21 presents the occupational distribution of additional solar jobs anticipated by employers by 1981. The largest increases (both absolute and proportional) were expected in skilled craft and operative occupations. Comparing the additional solar jobs anticipated with the 1978 occupational distribution suggests that, by 1981, the percentage of engineers and scientists in the solar workforce will decrease while the percentage of skilled crafts and operatives will increase. This shift would be consistent with increased commercialization of solar space heating and water heating technologies.

Table 22 presents the reported and estimated solar employment and anticipated additional solar jobs by geographic region. Solar employment was highest in Regions IX and III, and anticipated additional employment was highest in Regions IX and I. The largest proportional increases were expected in Regions VII and VI. (See Figure 1 for the definitions of regions.)

Reported solar employment and anticipated additional solar jobs are reported for each type of organization, type of industry and type of solar work in Appendix Tables C-20 through C-22. The largest proportional increases were anticipated in the fields of manufacturing and installation.

One of the objectives of the study was to identify new job specialties in the solar area. Only 27 percent of the respondents thought their professional, technical, or skilled craft employees performed tasks which were substantially different from those traditionally performed in similar, nonsolar jobs. The percentage of respondents who thought that solar tasks were substantially different from those traditionally performed was not significantly different among the different types of solar energy, different sizes of establishments, or different types of solar work at the 5 percent level of confidence. This finding indicates that employers, regardless of the type of solar energy the organization was involved with, the size of the establishment or the type of work engaged in, generally regarded the jobs in solar as comparable to nonsolar jobs in terms of the skills required to perform the job.

TABLE 21. OCCUPATIONAL DISTRIBUTION OF ADDITIONAL SOLAR JOBS, 1978. BASED ON 518 REPORTING ESTABLISHMENTS

Occupational Group	Reported Number of Additional Solar Jobs	%[a]	Estimated Number of Additional Solar Jobs[b]	Anticipated Percent Change (1978-1981)
Engineers	1,138	21.1	4,200	+ 60.1
Scientists	322	6.0	1,200	+ 60.9
Other Professionals	665	12.3	2,500	+ 76.0
Technicians	644	11.9	2,400	+ 93.2
Skilled Crafts and Operatives	1,517	28.1	5,600	+143.5
Clerical and Unskilled Workers	968	17.9	3,600	+ 87.8
No Occupation Given	143	2.6	--	--
Total, All Groups	5,397	100.0	19,400	+ 86.4

a Total may not add to 100% due to rounding.

b Includes allocation of "No Occupation Given" category/Detail may not add to total due to rounding.

TABLE 22. TOTAL EMPLOYMENT, SOLAR EMPLOYMENT, AND ADDITIONAL SOLAR JOBS BY GEOGRAPHIC REGION, 1978

Region	Reported Total Employment (N=548)	Reported Solar Employment (N=518)	Estimated Solar Employment	Reported Number of Additional Solar Jobs (N=518)	Estimated Number of Additional Solar Jobs	Anticipated Percentage Change (1978-1981)
I	39,448	818	2,900	859	3,100	+105.0
II	47,596	698	2,500	546	2,000	+ 78.2
III	139,096	1,041	3,700	810	2,900	+ 77.8
IV	31,397	570	2,100	420	1,500	+ 73.7
V	74,382	859	3,100	471	1,700	+ 54.8
VI	23,533	256	900	286	1,000	+111.7
VII	907	120	400	144	500	+120.0
VIII	11,134	411	1,500	394	1,400	+ 95.9
IX	100,660	1,373	4,900	1,417	5,100	+103.2
X	17,009	111	400	50	200	+ 45.0
Total	485,162	6,257	22,500	5,397	19,400	+ 86.3

A minority of respondents felt, however, that new or substantially different tasks were being performed by some of their solar employees. Table 23 presents a classification of the areas in which new skills and knowledge were required to perform these tasks. Special solar design, analysis, and installation skills were most frequently mentioned by respondents. New combinations of traditional skills were also mentioned. Based on the reported new skills and knowledge required, there appears to be a need for persons trained in the design and analysis of solar units, and for persons trained in installation of solar units. However, no new occupations unique to solar energy emerged as a result of this question, and a majority of respondents (including a majority of installers) did not regard the tasks performed as substantially different from traditional tasks. It appears that employees must be capable of performing traditional as well as purely solar work.

Characteristics of Solar Employees

A total of 483 employee questionnaires was received from 359 different establishments. The characteristics of the employee respondents were compared with occupational and solar work information supplied by the establishments. These comparisons indicated that the "other professional" occupational category was greatly overrepresented among the employee respondents, and the "skilled crafts and operatives" and "clerical and unskilled workers" categories were underrepresented. The type and phase of solar energy work reported agreed fairly well with the employment distribution provided by employers.

Employee respondents, however, overrepresented educational institutions and large establishments (over 400 employees). Thus, it does not appear that the employee respondents constituted a representative sample of employees working in solar energy. For this reason and because of the small number of questionnaires returned, caution should be used in interpreting the information obtained from the employee questionnaire.

TABLE 23. NEW SKILLS AND KNOWLEDGE NEEDED TO PERFORM SOLAR JOBS, 1978

Skill or Knowledge Area	Percent of Respondents (N=140)
Analysis Skills	32.1
Design Skills	41.4
Manufacturing Skills	15.7
Marketing Skills	5.0
Installation Skills	31.4
Systems Operation and Troubleshooting Skills	12.9
Skill in Conducting R&D in Specific Types of Solar Energy	17.9
New Combination of Skills	9.3
Other	26.4

Respondent employee characteristics are presented in Appendix Tables C-23 through C-31. Over 60 percent of the respondents were under 40 years old (Table C-27). Ninety percent were male. Respondents had been employed in solar-related work an average of only 3.7 years with a standard deviation of 3.6 years. This finding indicates the recent growth of the solar energy field and shows that many persons are new to the field. Most respondents did not have professional certification or journeyman licensing. Only 18.3 percent reported licensing related to their solar work.

Table 24 shows the relationship between current and previous occupations. For most employees, the current occupations category in solar was the same as the occupational category before working in solar. Those employees whose current occupational category was "other professional" showed the greatest diversity of previous occupations. Twenty percent of those employees came from engineering.

Hours Worked by Employees

The number of hours worked in solar activities and in nonsolar activities are important indicators of manpower utilization. Many persons working in the field were only working part-time in solar-related work. The mean number of hours spent in solar-related work actitivies during the week of June 11-17, 1978, was 29.9 hours per week with a standard deviation of 16.5 hours. The mean number of hours spent in nonsolar work activities during the same period was 13.4 hours per week with a standard deviation of 16.1 hours. The mean total hours worked during the period was 43.2 hours per week with a standard deviation of 9.8 hours. Approximately 6 percent of the 449 respondents worked less than 40 hours per week.

Approximately 4 percent of the respondents did not work in solar activities during the period (due to vacations or work variation), whereas 48 percent spent all their time (but sometimes less than 40 hours per week) in solar work. Since over half of the respondents worked less than full-time on solar activities, the existing manpower pool was clearly underutilized.

TABLE 24. RELATIONSHIP BETWEEN CURRENT OCCUPATION AND PREVIOUS OCCUPATION OF RESPONDENT EMPLOYEES, 1978

	Current Occupation											
	Engineer		Scientist		Other Professional		Technician		Skilled Cra and Operati	
Previous Occupation	N	%	N	%	N	%	N	%	N	%
Engineer	113	73.9	0	0.0	39	20.4	3	9.4	3	10.7
Scientist	5	3.3	31	77.5	12	6.3	1	3.1	0	0.0
Other Professional	9	5.9	2	5.0	101	52.9	3	9.4	3	10.7
Technician	1	0.7	0	0.0	3	1.6	19	59.4	1	3.6
Skilled Craft and Operative	2	1.3	0	0.0	5	2.6	1	3.1	17	60.7
Student/None	23	15.0	7	17.5	31	16.2	5	15.6	4	14.3
Total	153	100.0	40	100.0	191	100.0	32	100.0	28	100.0

The hours worked in solar (13,433 hours) represented 69 percent of the total hours worked during the period (19,456 hours). The total hours worked in the period represented 486.4 full-time equivalent employees. The hours worked in solar represented only 335.8 full-time equivalent employees (out of 449 respondents).

The percentage of hours spent in solar work varied significantly with the type of solar energy, phase of solar work, type of organization, industry category of the establishment, type of solar work of the establishment, and size of the establishment. The data are presented in Appendix Tables C-32 through C-37. Table 25 presents the average hours worked in solar by employees engaged in solar R&D work for each type of solar energy. These data were used to derive R&D employment coefficients in terms of labor hours per dollar of solar R&D funding.

Education and Training Needs of Employees

Table 26 presents the primary work activity reported by employees in each occupational group. It can be seen that a majority of engineers, scientists, and technicians worked primarily in R&D. Skilled crafts and machine operatives worked mainly in manufacturing and installation. These work activities and occupations naturally required different kinds and amounts of education and training. Table 27 presents the educational level of employees in each occupational group, and Table 28 presents the major field of study. Engineers generally possessed a baccalaureate or higher level degree in engineering, although there were a few nondegreed persons who, because of training and on-the-job experience, qualified as engineers. A majority of scientists possessed a doctoral level degree in the physical, mathematical, or biological sciences. Most personnel in the other professionals group had at least a baccalaureate level degree; 44 percent of this group had their degree in engineering. In terms of percentage with an advanced degree, the "other professionals" group also resembled the engineers. Technicians, skilled crafts, and machine operatives tended to have a high school level education or some college.

TABLE 25. AVERAGE HOURS WORKED IN SOLAR IN WEEK OF JUNE 11-17,1978 BY EMPLOYEES ENGAGED IN SOLAR R&D WORK BY TYPE OF SOLAR ENERGY

Type of solar energy	Number of Employees	Average Hours Worked
Space Heating and Cooling	74	28.3
Water Heating	11	34.7
Industrial Process Heat	8	26.6
Thermal Power	15	35.1
Ocean Thermal Conversion	12	22.4
Photovoltaic Conversion	30	32.3
Wind Conversion	9	21.2
Biomass Conversion	6	19.2
Other	9	39.8

TABLE 26. PRIMARY SOLAR WORK ACTIVITIES OF RESPONDENT EMPLOYEES BY CURRENT OCCUPATION, 1978 (PERCENT OF RESPONDENTS)

	Current Occupation					
Primary Solar Work Activity	Engineers (N=120)	Scientists (N=36)	Other Professionals (N=145)	Technicians (N=33)	Skilled Crafts (N=21)	
Research and Development	54.2	88.9	40.7	51.5	19.0	
Manufacturing	8.3	0.0	4.1	12.1	42.9	
Marketing and Distribution	10.8	2.8	19.3	9.1	4.8	
Installation and Maintenance	5.0	0.0	6.9	9.1	33.3	7.3
Other Commercial Activities	8.3	2.8	6.2	9.1	0.0	6.5
Other	13.3	5.6	22.8	9.1	0.0	15.2

TABLE 27. HIGHEST LEVEL OF FORMAL EDUCATION OF RESPONDENT EMPLOYEES BY CURRENT OCCUPATION, 1978 (PERCENT OF RESPONDENTS)

	Current Occupation					
Highest Level of Formal Education	Engineers (N=154)	Scientists (N=42)	Other Professionals (N=196)	Technicians (N=37)	Skilled Crafts (N=31)	
High school or less	1.3	0.0	2.0	13.5	38.7	
Some college	3.2	0.0	7.7	43.2	41.9	
Associate or technical degree	3.2	0.0	2.6	18.9	0.0	
B.A./B.S. degree	40.3	19.0	46.4	21.6	16.1	3[illegible]
M.A./M.S. degree	37.0	26.2	24.5	2.7	3.2	25.7
Ph.D., Ed.D., M.D. degree	14.9	54.8	16.8	0.0	0.0	17.2

TABLE 28. MAJOR FIELD OF STUDY OF RESPONDENT EMPLOYEES BY CURRENT OCCUPATION, 1978 (PERCENT OF RESPONDENTS)

	Current Occupation					
Major Field of Study	Engineers (N=155)	Scientists (N=42)	Other Professionals (N=195)	Technicians (N=37)	Skilled Crafts (N=30)	
Engineering	80.6	4.8	43.9	16.2	6.7	
Physical Science/Mathematics/Biology	6.5	90.5	12.2	10.8	10.0	
Other baccalaureate or professional fields	6.5	4.8	40.3	18.9	20.0	2
Fields of study below the baccalaureate level	6.5	0.0	3.6	54.1	63.3	12.2

Employees were asked about the need for special education and training in their job, the suitability of their education and training, and the source of any special education and training. Approximately 88 percent of the respondents felt that their job required special skills or knowledge. This finding does not necessarily contradict their employer's perception that most professional, technical and skilled craft employees working in solar energy did not perform tasks which are substantially different from those traditionally performed. The jobs may require special skills and knowledge which are not unique to solar energy work. Table 29 presents the special skills and knowledge areas required for the job as reported by employees in each current occupational group. Many of the special skills and knowledge required were not unique to solar energy, but rather represented traditional subject matter areas being applied to solar energy problems.

Respondents reported that an average of 19 percent of their work time in solar was spent on activities requiring more education and training than they had (Appendix Table C-38).

Table 30 presents the areas of special skill and knowledge in which employees felt they needed additional education and training. Since only 61 percent reported needing more education and training, this table is based on fewer cases than Table 29. About 50 percent of those needing more education and training identified analysis, design and evaluation of systems as the subject area needed. Approximately 25 percent reported needing additional education and training in the area of mechanical engineering, theromodynamics, and hydrodynamics. These same areas were among the most frequently reported areas required for the job (Table 29).

It is interesting to note in Table 29 that many skill and knowledge areas were required by all (or nearly all) occupations. Likewise, additional education and training in many of the same areas was needed by all (or nearly all) occupations (Table 30). However, the specific subject matter and technical level would probably vary by occupation, considering the differences in work activity and educational level previously described.

TABLE 29. SPECIAL SKILLS AND KNOWLEDGE REQUIRED BY EMPLOYEES BY CURRENT OCCUPATION, 1978 (PERCENT OF RESPONDENTS)

Skill and Knowledge Area	Current Occupation					
	Engineers (N=137)	Scientists (N=37)	Other Professionals (N=172)	Technicians (N=29)	Skilled Crafts (N=22)	
Knowledge of solar energy applications, technology and market	8.0	13.5	18.0	6.9	22.7	
Analysis, design and evaluation of systems	40.1	10.8	27.9	20.7	13.6	
Knowledge of manufacturing techniques	2.9	2.7	2.9	0.0	0.0	
Knowledge of existing government programs, policies, standards and laws regarding solar energy	1.5	0.0	5.2	0.0	0.0	2.
Economics, economic analysis and assessment	2.2	5.4	6.4	0.0	0.0	4.0
Knowledge of construction management, contracting, installation and maintenance	10.9	0.0	15.7	34.5	63.6	16.9
Marketing and sales skills	2.9	0.0	9.3	10.3	0.0	5.8
Mechanical engineering, thermodynamics and hydrodynamics	37.2	32.4	29.1	69.0	27.3	35.5
Other engineering	55.5	27.0	21.5	20.7	18.2	35.3
Physics and optics	11.7	43.2	9.9	10.3	4.5	13.4
Management	29.9	81.1	21.5	20.7	4.5	29.7
Social science, other professional	0.0	2.7	4.7	3.4	4.5	2.8
Other science (chemistry, mathematics, oceanography, systems)	5.8	2.7	18.6	3.4	13.6	11.6
Communication and research skills, miscellaneous abilities and formalized training	21.2	8.1	34.3	27.6	45.5	28.5

TABLE 30. ADDITIONAL EDUCATION AND TRAINING NEEDED BY EMPLOYEES BY CURRENT OCCUPATION, 1978
(PERCENT OF RESPONDENTS)

	Current Occupation					
Skill and Knowledge Area	Engineers (N=96)	Scientists (N=21)	Other Professionals (N=129)	Technicians (N=20)	Skilled Crafts (N=20)	
Knowledge of solar energy applications, technology and market	1.0	0.0	16.3	10.0	25.0	
Analysis, design and evaluation of systems	59.4	23.8	47.3	50.0	20.0	
Knowledge of manufacturing techniques	1.0	0.0	0.0	0.0	0.0	
Knowledge of existing government programs, policies, standards and laws regarding solar energy	2.1	0.0	5.4	0.0	0.0	
Economics, economic analysis and assessment	5.2	14.3	9.3	0.0	5.0	7.7
Knowledge of construction management, contracting, installation and maintenance	11.5	0.0	10.9	5.0	15.0	10.5
Marketing and sales skills	4.2	0.0	3.9	0.0	0.0	3.1
Mechanical engineering, thermodynamics and hydrodynamics	25.0	33.3	24.0	20.0	20.0	24.8
Other engineering	16.7	38.1	10.9	40.0	10.0	17.1
Physics and optics	2.1	28.6	3.9	20.0	5.0	6.3
Management	14.6	28.6	17.1	20.0	20.0	18.2
Social science, other professional	0.0	0.0	3.1	0.0	5.0	1.7
Other science (chemistry, mathematics, oceanography, systems)	6.2	0.0	4.7	0.0	10.0	4.9
Communication and research skills, miscellaneous abilities and formalized training	12.5	19.0	14.0	10.0	5.0	13.6

Table 31 presents the primary source of special skills and knowledge required by the job. Formal training and practical experience were the most frequently identified sources.

A majority of respondents (63 percent), however, had not completed any formal classroom training programs or courses in solar energy. Less than half of the respondents working in R&D, manufacturing, marketing and distribution, and installation and maintenance had completed any formal solar programs or courses (Appendix Table C-39).

Tabulations of the percentage of respondents who felt that their jobs required special skills or knowledge, and the percentage of respondents who completed formal solar training programs by phase of solar work, type of solar energy, industrial category of establishment, and type of solar work of establishment are presented in Appendix Tables C-39 through C-42.

Those respondents who reported that their job required special skills or knowledge were more likely to have completed formal solar training programs than those who did not feel that their job required special skills or knowledge. The relationship was significant beyond the 5 percent level of confidence (Appendix Table C-43).

Table 32 presents the most frequently taken subjects and their average duration. Most courses averaged between 20 and 40 hours. Appendix Table C-44 presents the subject matter and average duration of all reported solar training programs and courses. Table 33 indicates that 58 percent of these courses were provided by colleges or universitities.

Employment Projections

An objective of the study was to develop and apply a methodology for projecting future employment in solar energy. Two separate projection methods were developed; one for forecasting R&D solar employment, and one for forecasting commercial solar employment. Both methods were used to project solar employment for three years (to 1981) and five years (to 1983). The projecion methods and results are presented in Appendix D.

TABLE 31. PRIMARY SOURCE OF SPECIAL SKILLS AND KNOWLEDGE AS REPORTED BY EMPLOYEES, 1978

Source	Percent of Respondents (N=393)
Self study	14.8
Practical experience	41.2
Formal training	44.0

TABLE 32. SUBJECT MATTER AND AVERAGE DURATION OF THE FOUR MOST FREQUENTLY TAKEN TRAINING PROGRAMS OR COURSES AS REPORTED BY EMPLOYEES, 1978

Subject Matter	Number of Training Programs or Courses Taken	Average Duration in Hours
Solar Energy, general	154	19.9
Space Heating and Cooling	40	29.9
Solar System Design	27	23.8
Thermodynamics/Heat Transfer	16	37.9

TABLE 33. PROVIDERS OF SOLAR ENERGY PROGRAMS OR COURSES AS REPORTED BY EMPLOYEES, 1978

Provider	Percent of Courses Taken (N=355)
Employer	6.5
Vocational or Trade School	4.2
College or University	57.7
Professional or Technical Society	16.1
Government	4.8
Manufacturer	5.1
Other	5.6

The projections of R&D solar employment were based on projected Federal funding of solar R&D and on the proportions of solar R&D expenditures which were Federally financed (as reported in Table 10). Each type of solar energy was treated separately. In deriving the projections, it was assumed that R&D employee productivity will remain constant through 1983, and that R&D productivity is not related to establishment size. Further assumptions were made with regard to the rate of decline in Federal involvement in R&D financing for each type of solar energy.

The projections of commercial solar employment were based on labor coefficients, defined in terms of labor-hours per unit of installed solar equipment. Only solar space heating and cooling, water heating, and industrial process heat were assumed to produce significant commercial employment by 1983. The employer survey did not provide information necessary to compute the commerical labor coefficients because companies considered sales data to be proprietary information. Estimates of the labor coefficients for production and installation of solar units were obtained from a small sample of companies. The available estimates of labor coefficients, as well as the estimates obtained and used in this study, are highly variable from company to company. The changing proportions of different types of collectors and concentrators used and productivity changes were estimated to 1983. Projections of commercial solar equipment sales were obtained from published sources. These sales forecasts were applied to the estimated labor coefficients to obtain the projections of commercial solar employment.

Table 34 presents the projected changes in solar employment for R&D and commercial activities. Full-time equivalent R&D employment is projected to increase by 74 percent by 1981 and by 144 percent by 1983. Commercial solar employment is projected to increase by 137 percent by 1981 and by 202 percent by 1983. The commercial employment projections agree closely with the average anticipated gains in commercial solar sales reported by employers for 1981 (134 percent) and 1983 (194 percent). Full-time equivalent employment for R&D and commercial activities is projected to double by 1981 and nearly triple by 1983, based on projections of recent trends in Federal R&D funding and commercial solar sales. The overall projected increase by 1981 (102 percent) is slightly larger than

Table 34. PROJECTED CHANGES IN FULL-TIME EQUIVALENT SOLAR EMPLOYMENT, 1978

Activity	FTE Employment 1978	FTE Employment 1981	Percentage Change 1978 - 1981	FTE Employment 1983	Percentage Change 1978 - 1983
R&D	9,111	15,852	74.0	22,245	144.2
Commercial	7,296	17,282*	136.9	22,120*	203.2
Total	16,407	33,134	102.0	44,365	170.4

*Based on recent trends.

the percentage of additional solar jobs anticipated by employers by 1981 (86 percent). Employer forecasts of additional jobs appear more conservative than their forecasts of additional solar sales. This difference may be due to the employers' expectation of utilizing more of the time of current employees in solar work, or of using the existing production and installation capability more efficiently. Either alternative would result in fewer additional employees compared to increased sales.

The projections in Table 34, based as they are on many assumptions and limited data, should be regarded with caution. The projections can not anticipate technological breakthroughs in production and installation techniques, improvements in system cost-effectiveness, changes in incentives to purchase solar units, or major shifts in Federal funding of solar R&D.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Solar energy is a relatively new and developing energy field. Approximately 2,000 establishments (both private and public) are engaged in solar energy activities. About 70 percent of these establishments are private industry and construction contractors. Most of the establishments are small. Approximately 60 percent have 40 or fewer employees. Many establishments have only recently been formed. No single industrial classification dominates the field.

Work is being conducted in many different types and applications of solar energy. Approximately 75 percent of the establishments are primarily engaged in work in space heating and cooling and water heating. Any one establishment, however, is frequently involved in many different types of solar energy and in many different phases of solar work. Approximately half of all solar work currently is research and development work, and approximately half of all solar employment is in research and development activities.

Small establishments tend to be nearly 100 percent involved in solar energy work, whereas large establishments tend to have only a small percentage of their employees working in solar. Solar installation and architectural and engineering services are performed mainly by small organizations, and solar R&D is performed mainly by large organizations.

It is estimated that about 22,500 employees were engaged in solar energy work (direct and indirect) in 1978. Not all employees worked full time in solar energy. The average hours spent on solar-related work, as reported by a sample of employees, was approximately 30 hours per week.

The most frequently reported occupation in solar R&D activities is mechanical engineering. Approximately 40 percent of all employees engaged in R&D are engineers. The most frequently reported occupation in solar installation activities is plumbing/pipe fitting. Nearly half of all employees engaged in installation are skilled crafts workers. Skilled and unskilled workers comprise over half of all employees engaged in other solar commercial activities.

Many solar energy jobs require special skills or knowledge concerning solar energy technology, the application of traditional skills to solar energy work, and combinations of traditional skills. However, new occupational specialties are rarely reported, and most employees must be capable of performing traditional as well as purely solar work.

The most difficult to hire solar occupations include engineers, atmospheric scientists, operations/systems researchers, and college/university teachers. The least difficult to hire solar occupations include clerical, unskilled, and skilled workers.

Full-time equivalent employment in solar R&D is projected to increase 74 percent by 1981 and 144 percent by 1983, based on projections of solar R&D funding. Full-time equivalent commercial solar employment (direct labor for production and installation) is projected to increase 137 percent by 1981 and 203 percent by 1983, based on recent trends projections of commercial solar equipment sales. Overall, full-time equivalent employment is projected to double by 1981 and increase by 170 percent by 1983.

Recommendations

A series of five recommendations are briefly presented below.

Recommendation 1

It is recommended that the Department of Energy conduct or support periodic surveys of establishments engaged in solar energy activities to determine employment and occupational distributions. The current study provides baseline information on employment and occupations. Much detailed information was obtained. Future surveys should not require the same amount of detail, and the reporting burden will therefore be less. The current survey should be updated every 2-3 years, based on the anticipated growth in employment.

The current study provides a comprehensive directory of establishments engaged in solar energy activities. Because solar energy is such a

new field, establishments are entering and leaving the field at a high rate. The current list, therefore, should be updated periodically. It would also be helpful if additional identifying information such as establishment size, type of solar energy, and type of solar work (manufacturing, installation, education, R&D) were available on all establishments in the list. The additional information would be used in contacting representative samples or special samples of establishments, and in evaluating the representativeness of respondents.

The current study provides a system for collecting and reporting data concerning solar energy manpower. Methods for improving the response of employers and employees should be developed. A larger, more representative sample of employees should be obtained.

Recommendation 2

It is recommended that solar energy employees be identified in existing occupational surveys, such as the National Sample of Scientists and Engineers, sponsored by the National Science Foundation, the National Industry-Occupation Employment Sample, conducted by the Bureau of Labor Statistics, and other post-censal surveys.* This can be accomplished by incorporating various energy identification questions into the surveys. The solar energy questions should identify the type of solar energy technology or application and the phase of solar energy work of the individual. This procedure would permit a more exact determination of the number and characteristics of persons engaged in solar energy work.

Recommendation 3

It is recommended that the Department of Energy obtain information concerning solar energy manpower supply. The current survey provided estimates and projections of employment. Comparable information on supply is

* Under DOE support, scientists and engineers engaged in energy-related work are currently identified in the National Science Foundation surveys of scientists and engineers and new science and engineering entrants.

needed to form a complete assessment of solar energy manpower. Information should be solicited from colleges and universities, technical institutes, vocational secondary schools, company or union training programs, and any other sources of solar energy manpower. The information solicited should include number of persons being trained in solar, curricula, placement, follow up, and sources of trainee support.

Recommendation 4

It is recommended that the Department of Energy obtain improved estimates of labor requirements for production and installation of different types of solar energy systems (primarily active solar space and water heating systems). Although the technology in this field is constantly changing, there is a critical need for more reliable and complete estimates from which manpower requirements can be derived. Rather than rely on industry estimates, a detailed process analysis should be conducted for different types of installations and different climates. The number and occupational distribution of labor (direct and support) required should be determined. Labor rates and required levels of experience should also be investigated.

Recommendation 5

It is recommended that the Department of Energy obtain improved regional and state projections of future solar energy manpower and occupational needs. The current projections have been made on a national basis. In this form their utility is limited to aggregated, macro-economic and national policy analyses. These data would be more useful to all levels of government if they could be disaggregated by state. Most inquiries for information concerning future employment in solar energy will be couched in state or regional terms.

APPENDIX A

SURVEY QUESTIONNAIRES, SCREENING FORM AND COVER LETTERS

DOE Cover Letter for Employer Questionnaire

Department of Energy
Washington, D.C. 20545

Dear Sir/Madam:

The United States Department of Energy (DOE) has initiated a study to assess the present employment and utilization of solar energy manpower and to produce a methodology for estimating future manpower requirements in the solar energy field. We want to assure that the development of solar technologies can proceed without constraints caused by manpower problems. Your participation in this survey will be of great assistance in establishing a data base for determining future needs for qualified personnel.

DOE has requested Battelle's Columbus Laboratories, a private, not-for-profit research institute, to conduct this solar energy manpower assessment. The enclosed questionnaire is designed to gather the information needed to characterize present manpower utilization in solar and solar related energy areas and to project and characterize future manpower needs. Participation in the survey is voluntary; however, your cooperation in completing and returning this questionnaire will be of great usefulness in planning for the orderly development of the solar energy field. If y are not the appropriate person within your organization to complete this questionnaire, please give this material to the appropriate person.

Your response to the questionnaire will be combined with those of other reporting organizations. Information furnished by individual organizations will not be reported or disclosed. Averages and other statistical measures will be used to characterize manpower requirements in solar energy. Your organization's responses to the questionnaire will be kept in complete confidence by Battelle and identifying information will not be released to DOE or any other party.

Please return the completed questionnaire within two weeks. A stamped return envelope is enclosed for your convenience. Return of the questionnaire will give Battelle's Columbus Laboratories consent to use the information which you have provided only for the purposes and under the conditions described above.

If you have any questions about the study or the questionnaire, please call Ms. Sandy Newman at Battelle Laboratories, collect, (614) 424-5646.

Thank you for your cooperation.

Sincerely,

Lawrence G. Stewart
Director
Office of Education, Business
and Labor Affairs

Letter of Endorsement
Sent with Employer Questionnaires.

SOLAR ENERGY INDUSTRIES ASSOCIATION Suite [illegible]

Dear Sir or Madam:

Working under a contract with the Department of Energy, the Battelle Columbus Laboratories are conducting a survey of the present status of manpower within the industry and future manpower requirements. The results of this survey should help in formulation of manpower training policies and assist in guiding them in directions which will be most advantageous to our industry.

Accordingly, I urge you to invest the time needed to respond fully to the enclosed questionnaire.

Cordially,

S. H. BUTT, President
Solar Energy Industries Association

/crc
enc.

Battelle
Columbus Laboratories

OMB No. 38-S-77-003
Approval Expires
June 30, 1979

SOLAR ENERGY MANPOWER SURVEY
EMPLOYER FORM

The information collected on this form will be held in strict confidence and will be used for statistical purposes only. The information will only be released in a form which does not identify information about any particular organization. Your voluntary cooperation is needed to make the results of this survey comprehensive, accurate and timely. Please return this questionnaire within 2 weeks. The enclosed return envelope requires no postage.

1. Please make any corrections on this label.

cc 1–6
1–cc 7

IN COMPLETING THIS FORM, PLEASE CIRCLE THE APPROPRIATE RESPONSE UNLESS INSTRUCTED OTHERWISE.

2. Do you wish to receive a report on the findings of this survey?
Circle the appropriate response. 1. Yes 2. No

cc 8

3. SCOPE OF SURVEY

Data should be provided for a single establishment, defined as an administratively independent unit, together with any subdivisions, which may be physically separate but are administratively dependent upon the establishment.

For the purposes of this survey, an establishment is considered to be in solar or solar related energy work if it is engaged in any of the activities listed in the definitions on page 8. On this basis –

Were any employees of this establishment engaged in solar or solar related energy activities during the pay period which included April 12, 1978? Circle the appropriate response. 1. Yes 2. No.

cc 9

If you circled 'Yes' please complete the remainder of the questionnaire.

If you circled 'No' please return this questionnaire to avoid further correspondence. Thank you for your cooperation.

4. **TYPE OF ORGANIZATION**

Which of the following best describes your establishment? Circle one answer only.

1. Private industry or business (excluding construction contracting).
2. Construction contractor.
3. Federal government.
4. State or local government (excluding educational institutions).
5. Private, nonprofit organization (excluding educational institutions).
6. Educational institutions.
7. Other (specify)_____

cc 10

5. **PRIMARY ACTIVITY**

Examine the list of products and services presented below. What is the most important product or service provided by your organization? If your establishment is part of a larger organization, circle the code number which best describes the primary activity of the larger overall organization. Otherwise, circle the code number which best describes the primary activity of your particular establishment.

LIST OF PRODUCTS AND SERVICES FOR SELECTING PRIMARY ACTIVITY

Code	Production and Manufacturing
01	Agriculture, forestry and fishing
02	Mining
03	General building contracting
04	Special trade contracting
05	Manufacture of food and kindred products
06	Tobacco manufacturing
07	Textile mill products
08	Manufacture of apparel and textile products
09	Manufacture of lumber and wood products
10	Manufacture of furniture and fixtures
11	Manufacture of paper and allied products
12	Manufacture of chemicals and allied products
13	Manufacture of petroleum and coal products
14	Manufacture of rubber and plastic products
15	Manufacture of leather and leather products
16	Manufacture of stone, clay and glass products
17	Primary metals manufacturing
18	Fabricated metal products manufacturing
19	Manufacture of machinery, except electrical
20	Manufacture of electric and electronic equipment
21	Manufacture of transportation equipment
22	Manufacture of instruments and related products
23	Other manufacturing (specify)_____

Code	Services
30	Transportation, communication and public utility
31	Wholesale or retail trade
32	Finance, insurance and real estate services
33	Personal services
34	Business services
35	Repair services
36	Educational services
37	Engineering and architectural services
38	Research services
39	Public administration, including regulation
40	Other services (specify)_____

6. SOLAR PRODUCTS OR SERVICES

6.1 Which of the following types of solar energy apply to your establishment? (The different types of solar energy are defined on page 8.) Place a check mark (√) next to all that apply.

TYPES OF SOLAR ENERGY

Space Heating and Cooling	13	Photovoltaic Conversion	18
Water Heating	14	Wind Conversion	19
Industrial Process Heat	15	Biomass Conversion	20
Thermal Power	16	Other (specify)_____	21
Ocean Thermal Conversion	17	_____	

6.2 When you have completed Item 6.1, place a circle around the check mark ((√)) that represents the work activity in solar or solar related energy in which your establishment has the greatest number of employees. (This should typify your establishment's solar activity.) Only circle one check mark. cc 22–23

6.3 Briefly describe the two principal solar related products or services which you sell or provide. Please use descriptive or generic words (such as flat plate collectors) rather than trade names.

_____

_____ cc 24–26

_____

_____ cc 27–29

6.4 What percentage of your organization's work in solar energy is in solar research and development and what percentage is in commercial solar activities? (See definitions on page 8.) Your answer to this question should add up to 100%.

Research and Development		cc 30–32
Commercial Activities		cc 33–35
Total	100%	

7. EMPLOYMENT SUMMARY

Data should be provided for a single establishment and should relate to the payroll period which included April 12, 1978.

7.1 Total Employment. What is the total number of employees in your establishment? (include all personnel whether or not engaged in solar related energy activities) . . . . . cc 36–39

7.2 Total Employment in Solar or Solar Related Energy Activities. Of the total number of employees reported above, how many were working in solar or solar related energy activities? . . . . . cc 40–43

8. NEW JOB SPECIALITIES

8.1 Do your professional, technical, or skilled craft employees, working in solar energy, perform tasks which are substantially different from those traditionally performed?

Circle the appropriate response. 1. Yes 2. No cc 44

8.2 If you responded "Yes" to Item 8.1, briefly describe each new job in terms of the new tasks which are required to perform these solar energy jobs. Your description should reference the type of solar energy involved in the new or different jobs, and the new skills or knowledge required.

DESCRIPTION OF THE NEW TASKS REQUIRED TO PERFORM SOLAR ENERGY JOBS	
JOB 1.	
	cc 45–46
JOB 2.	
	cc 47–48
JOB 3.	
	cc 49–50
JOB 4.	
	cc 51–52

9. OCCUPATIONAL EMPLOYMENT IN SOLAR OR SOLAR RELATED ENERGY ACTIVITIES

(As of payroll period which included April 12, 1978.)

From the list of occupational titles on page 9, select the closest occupational titles which describe your professional, technical, and skilled craft employees who are working in solar or solar related energy. Enter occupational titles in Column 1.

Then for each occupational title, enter the number of employees in your establishment in Column 2 who primarily work in solar research and development and in Column 3 the number of those who primarily work in commercial solar activities. (Do not count an employee in more than one occupation or in more than one phase of work.)

Then in Column 4 place a check mark (√) in the row of each occupation listed in Column 1 where your establishment is currently having difficulty in hiring qualified personnel to fill budgeted solar related vacancies. Finally in Column 5, enter the estimated number of additional jobs which your establishment will add over the next 3 years, for each occupation which you listed in Column 1.

(1) OCCUPATIONAL TITLES (From Page 9)	(2) NUMBERS IN RESEARCH AND DEVELOPMENT	(3) NUMBERS IN COMMERCIAL ACTIVITIES	(4) CHECK IF DIFFICULT TO HIRE	(5) NUMBER OF ADDITIONAL JOBS 1978–1981	
					Dup 1–6 2–cc 7
8–9	10–13	14–17	18	19–21	
					cc 22–35
					cc 36–49
					cc 50–63
64–65	66–69	70–73	74	75–77	Dup 1–6 3–cc 7
					cc 8–21
					cc 22–35
					cc 36–49
					cc 50–63
64–65	66–69	70–73	74	75–77	Dup 1–6 4–cc 7
All Other Employees in Solar or Solar Related Activities (unskilled, clerical, etc.)	8–11	12–15	16	17–19	

The total of these two columns should equal the number of employees reported in Question 7.2

10. SOURCE OF FUNDS USED TO FINANCE SOLAR ACTIVITIES

For each type of solar energy work in which your establishment is engaged, indicate the percentage of support received from each of the sources shown in the columns. The sum of each row in which you make an entry should add up to 100%. The different types of solar energy are defined on page 8.

SOURCE OF FUNDS USED TO FINANCE SOLAR ACTIVITIES

TYPES OF SOLAR ENERGY	Research and development funded by federal government	Research and development funded by other sources	Commercial solar activities funded internally from sales revenues, debt capital or equity capital	Other (specify)	TOTAL	
Space heating and cooling	20–22	23–25	26–28	29–31	100%	cc 32–43
Water heating					100%	cc 44–55
Industrial process heat					100%	cc 56–67
Thermal power					100%	cc 68–79
Ocean thermal conversion	68–70	71–73	74–76	77–79	100%	Page 9
Photovoltaic conversion					100%	cc 8–19
Wind conversion					100%	cc 20–31
Biomass conversion					100%	cc 32–43
Other (specify)_____					100%	cc 44–55

11. FUTURE COMMERCIAL SOLAR SALES

What percentage increase or decrease in commercial solar sales (excluding research and development) do you anticipate in 1979, 1981, and 1983? If your establishment currently has commercial sales, enter the anticipated percentage change from 1978 in your establishment's commercial solar sales for each of the requested years. Use 1978 as a base for each year. Use your establishment's usual annual fiscal period and estimate the percentage change in constant 1978 dollars (i.e., do not allow for inflation). Indicate a percentage increase with a plus sign (+) and a percentage decrease with a minus sign (−). If your establishment does not have commercial sales, enter NA (not applicable) in each box.

ANTICIPATED PERCENTAGE CHANGE IN COMMERCIAL SOLAR SALES FROM 1978		
1979	1981	1983
cc 56–59	cc 60–63	cc 64–67

THANK YOU FOR YOUR COOPERATION

DEFINITIONS

Types of Solar Energy

Space heating and cooling: the transmission and storage of solar thermal energy using solar collectors, some transmission medium, and storage facilities. Includes passive and active residential or commercial solar heating or cooling of human, plant or animal shelters.

Solar water heating: the transmission and storage of solar thermal energy using solar collectors, heat exchangers, and some transmission medium. Includes passive and active residential or commercial solar water heating and swimming pool heating.

Industrial process heat: the transmission of solar thermal energy for various industrial applications using solar collectors and some transmission medium. Includes crop dryers.

Thermal power: the use of concentrating solar collectors, heat absorbers, boilers, and heat exchangers, etc., to generate electricity. Includes irrigation systems.

Ocean thermal conversion: the generation of electricity by use of the temperature difference between surface and deep water.

Photovoltaic conversion: the generation of electricity by allowing sunlight to fall upon two dissimilar substances in what is commonly called a solar cell.

Wind conversion: the generation of energy through the use of machines consisting of revolving blades or airfoils.

Biomass conversion: the cultivation and chemical processing (via fermentation, pyrolysis, or combustion) of terrestrial or aquatic plants for the purpose of creating chemical energy, fuels, or chemical feedstocks.

Phases of Solar and Solar-Related Energy Work

Research and Development: theoretical or experimental investigations directed toward the acquisition of new or fuller scientific knowledge of the subject studied, or systematic application of scientific knowledge directed toward the creation of new or substantially improved equipment, processes, procedures, and techniques in any area of solar energy; or prototype design and engineering of solar energy hardware components and/or systems.

Commercial Phase

Manufacturing: the mechanical or chemical transformation of materials into components designed specifically for application in a solar energy system; also, the assembly of solar components and other materials into solar energy systems.

Marketing and Distribution: the process of estimating the demand for a product, promoting the product, transporting the product and selling the product.

Installation and Maintenance: specialized activities, such as plumbing, electrical wiring, metal and glass working, etc., required to emplace or prepare solar energy components and/or systems for actual operation; also, specialized repair services required to locate or correct failures in components and/or solar energy systems.

Other Commercial Activities: customer design, routine product testing and quality control, engineering and consulting services to licensees, experimental work needed for patent litigation, etc.

LIST OF OCCUPATIONS

ENGINEERS – Persons engaged in engineering work which requires at least a bachelor's degree, or its equivalent in education and experience

Agricultural Engineers
Architectural Engineers
Civil Engineers
Electrical and Electronic Engineers
Industrial Engineers
Mechanical Engineers
Metallurgical and Materials Engineers
Other Engineers – specify

SCIENTISTS – Persons engaged in scientific work which requires at least a bachelor's degree, or its equivalent in education and experience.

Agricultural Scientists
Atmospheric Scientists and Meteorologists
Biological Scientists
Chemists
Computer Specialists
Earth Specialists
Marine Scientists and Oceanographers
Mathematicians and Statisticians
Physicists and Astronomers
Other Scientists – specify

OTHER PROFESSIONALS – Persons engaged in work, other than science and engineering, which requires at least a bachelor's degree, or its equivalent in education and experience.

Architects
Economists
Operations and Systems Researchers and Analysts
Urban and Regional Planners
College and University Teachers – specify subject
Construction Managers
Managers of Scientists, Engineers, and Technicians
Other Professional Occupations – specify

TECHNICIANS – Persons engaged in technical work in science or engineering, which requires some post-high school training, but less than a bachelor's degree.

Agricultural and Biological Technicians
Chemical Technicians
Electrical and Electronic Engineering Technicians
Industrial Engineering Technicians
Mathematical Technicians
Mechanical Engineering Technicians
Other Technicians – specify

SKILLED CRAFTS AND OPERATIVES – Persons engaged in the operation of industrial equipment, or in a craft or manual occupation, which requires a high degree of manual dexterity and independent judgment.

Asbestos and Insulation Workers
Air-Conditioning, Heating and Refrigeration Workers
Boilermakers
Carpenters
Cement and Concrete Finishers
Electricians
Glaziers
Heat Treaters, Annealers, and Temperers
Heaters, Metal
Machinists
Mechanics
Metal Molders
Metal Platers
Opticians, and Lens Grinders and Polishers
Pattern and Model Makers
Plumbers and Pipe Fitters
Precision Machine Operatives
Riveters and Fasteners
Rollers and Finishers, Metal
Roofers and Slaters
Sheetmetal Workers and Tinsmiths
Solderers
Structural Metal Craftsmen
Tool and Die Makers
Welders and Flame-Cutters
Other Craft and Operative Occupations – specify

Battelle Cover Letter to Group 1
Employers Explaining Employee Questionnaire

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

Dear Sir or Madam:

Thank you for your response to Battelle's Solar Energy Manpower Survey. I am pleased that you have supported our effort with your time and establishment data. At the completion of the study Battelle will provide you with the results of the survey, and a report that will indicate projected solar energy manpower requirements.

I am soliciting your further support to obtain more detailed data on the characteristics of persons working in the solar energy field. Your role in this phase of Battelle's study will be to select a sample of employees who will receive a survey form on their work and experience, and to forward the enclosed material to the person or persons selected. As with the Employer Form you completed, employee responses will be anonymous. Furthermore, no where in our report will replies from your employees be associated with your organization.

Employees selected are to send their forms directly to Battelle; therefore, you will not be responsible for gathering and forwarding any material. In the event that forms are not returned by employees we ask that you distribute follow-up letters to the employees selected.

Instructions for sampling employees and distributing materials are enclosed along with the appropriate number of survey packages. I hope that after reviewing the instructions you will lend your continued support to this study. Thank you in advance for your assistance.

Sincerely,

Girard W. Levy

Girard W. Levy
Project Director

GL:kc

Instructions for the Distribution of Employee Questionnaires

The number of solar energy employees of your establishment was reported to be _____. In order to insure a random sampling of these employees, please follow the simple procedure below.

1. List the names of your solar energy employees alphabetically, or use an already existing listing of these employees (such as a payroll list, department/division membership roll, badge number list, etc.).

2. Select ____ employees from the list. These employees should correspond to the following positions in the list:

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

3. Distribute one package of materials to each employee selected. Instructions for completing and returning the forms directly to Battelle are enclosed in the package.

For your own information, please keep a listing of persons receiving the materials, the space above is provided for that purpose. Do not give employees names to Battelle, or mark them on the forms.

4. Forms are to be filled out and returned to Battelle within two weeks.

THANK YOU FOR YOUR COOPERATION.

Note: The number of employees was selected according to the sampling plan shown in Table 1. The ordinal positions in the list were randomly selected.

DOE Cover Letter for Employee Questionnaire

Department of Energy
Washington. D.C. 20545

Dear Sir/Madam:

The United States Department of Energy (DOE) has begun a study to describe the jobs in the solar energy field, and to anticipate future job needs. We want to make sure that enough adequately trained people will be available to develop and use solar energy to its full potential.

DOE has asked Battelle's Columbus Laboratories (a not-for-profit research institute) to conduct this study. They have prepared some questions about your present job and your training. Answering the questions is voluntary. Because you work in a solar energy job, your answering and returning the questionnaire will be of great help to us.

Your answers will be kept in complete confidence. They will not be shown to your employer or any other party. Your answers will be combined with those of other employees. Your name will not appear in any report.

Please return the completed questionnaire as soon as possible, but within 2 weeks at the latest. A stamped return envelope is enclosed for your use. Return of the completed questionnaire gives permission for use of the answers only for the purposes and under the conditions which have been described.

If you have any difficulty understanding or answering the questions, call Ms. Sandy Newman at Battelle Laboratories, collect, (614) 424-5646.

Thank you for your cooperation.

Sincerely,

Lawrence G. Stewart

Lawrence G. Stewart
Director
Office of Education, Business
and Labor Affairs

Battelle
Columbus Laboratories

OMB No. 38-S-77-003
Approval Expires
June 30, 1979

EMPLOYEE FORM

The information collected on this form will be held in strict confidence and will be used for statistical purposes only. The information will only be released in a form which does not identify information about any particular person. Your voluntary cooperation is needed to make the results of this survey comprehensive, accurate and timely. Please return this questionnaire within 2 weeks. The return envelope requires no postage.

IN COMPLETING THIS FORM, PLEASE CIRCLE YOUR ANSWER UNLESS INSTRUCTED OTHERWISE. cc 1–7 1–cc 8

1. Is any portion of your current work in solar or solar related energy? (See definitions on page 8.

   Circle your answer. 1. Yes 2. No cc 9

   If you circled 'Yes', please complete the remainder of the questionnaire.

   If you circled 'No', please return this questionnaire so that our records will be complete. Thank you for your cooperation.

2. How old are you (in years as of your most recent birthday)?

   Fill in your age in the box . . . . . cc 10–11

3. Sex: Circle your answer. 1. Male 2. Female cc 12

4. What is the total number of years that you have been employed in solar or solar related energy work? Fill in the number of years in the box. cc 13–14

5. What was your occupation before working in solar energy? Write your response in the space provided. Please be as specific as possible (for example, electrical engineer rather than just engineer). If you were a student, write in "student". If you had no occupation, write in "none".

   _____

   _____

   _____ cc 15–16

6. From the list of occupations below select the one which best describes your current occupation, and circle the code number. If your occupation is not listed choose the closest "other" category and circle the code number. Be sure to choose the occupation that you are currently working in, even though it may be different from the occupation which you were trained for.

PROFESSIONAL AND TECHNICAL OCCUPATIONS

Code		Code	
01	Agricultural engineers	20	Architects
02	Architectural engineers	21	Economists
03	Civil engineers	22	Operations and systems researchers and analysts
04	Electrical and electronic engineers	23	Urban and regional planners
05	Industrial engineers	24	College and university teachers (solar energy related subjects)
06	Mechanical engineers	25	Construction managers
07	Metallurgical engineers	26	Managers of scientists, engineers, and technicians
08	Other engineers	27	Other professional occupations
10	Agricultural scientists	30	Agricultural and biological technicians
11	Atmospheric scientists and meteorologists	31	Chemical technicians
12	Biological scientists	32	Electrical and electronic engineering technicians
13	Chemists	33	Industrial engineering technicians
14	Computer specialists	34	Mathematical engineering technicians
15	Earth scientists	35	Mechanical engineering technicians
16	Marine scientists and oceanographers	36	Other technicians
17	Mathematicians and statisticians		
18	Physicists and astronomers		
19	Other scientists		

SKILLED CRAFT AND OPERATIVE OCCUPATIONS

Code		Code	
50	Asbestos and insulation workers	63	Opticians, and lens grinders and polishers
51	Air-conditioning, heating and refrigeration workers	64	Pattern and model makers
52	Boilermakers	65	Plumbers and pipe fitters
53	Carpenters	66	Precision machine operatives
54	Cement and concrete finishers	67	Riveters and fasteners
55	Electricians	68	Rollers and finishers, metal
56	Glaziers	69	Roofers and slaters
57	Heat treaters, annealers, and temperers	70	Sheetmetal workers and tinsmiths
58	Heaters, metal	71	Solderers
59	Machinists	72	Structural metal craftsmen
60	Mechanics	73	Tool and die makers
61	Metal molders	74	Welders and flame-cutters
62	Metal platers	75	Other craft and operative occupations

cc 17–18

7. Of your total work activities for your solar energy employer during the week of June 11–17, 1978, indicate the number of hours that you spent in solar or solar related work activities, and the number of hours that you spent in nonsolar work activities.

	Hours Worked in the Week of June 11–17, 1978	
Solar or solar related activities		cc 19–20
Nonsolar activities		cc 21–22
TOTAL		cc 23–24

8. Place a check (√) in the box or boxes which represent your present work activities in solar or solar related energy. You may check as many as apply to your work. Then circle the check (Ⓥ) that represents the one area in which you spend most of your time. (Only one check should be circled.)

	Research and Development	Manufacturing	Marketing and Distribution	Installation and Maintenance	Other Commercial Activities	Other (specify)	
Space heating and cooling	25	26	27	28	29	30	cc 31–36
Water heating							cc 37–42
Industrial process heat							cc 43–48
Thermal power							cc 49–54
Ocean thermal conversion							cc 55–60
Photovoltaic conversion							cc 61–66
Wind conversion							cc 67–72
Biomass conversion							cc 73–78
Other (specify) _____							cc 79–80

Dup 1–7
2–cc 8

9. What is the highest level of formal education that you have completed? Circle only one answer.

1. Less than high school
2. High school diploma or equivalent
3. Some college, but no degree
4. Associate or technical degree
5. Bachelor's degree
6. Master's degree
7. Ph.D., Ed.D., M.D.
8. Other (specify) _____

cc 9

10. Indicate your major field of study for your highest level of education by circling the number in the list below. If your major field of study is not listed, choose the closest other category (30, 60 or 61) and explain below. If you have not participated in a formal educational program beyond the high school level, circle 70 below.

Fields of Study Leading to Bachelor's or Higher Degrees

01 Biological and agricultural science
02 Atmospheric science and meteorology
03 Chemistry
04 Physics and astronomy
05 Earth science
06 Oceanography and marine science
07 Mathematics, statistics, and computer science

10 Education
11 Management and business
12 Arts and humanities
13 Health and medical science
14 Social and behavioral science
15 Economics
16 Urban and regional planning

20 Architecture and architectural engineering
21 Civil engineering
22 Electrical and electronic engineering
23 Industrial engineering
24 Mechanical engineering
25 Metallurgical and materials engineering

30 Other (specify) _____

Fields of Study and Occupational Training Below the Bachelor's Degree

40 Computer programming and data processing
41 Drafting and design
42 Air-conditioning, heating and refrigeration technology
43 Civil engineering technology
44 Electrical and electronic technology
45 Industrial engineering technology
46 Mechanical engineering technology
47 Metallurgical and materials technology

50 Biological and agricultural technology
51 Chemical technology
52 Physical science technology
53 Statistical and computational technology

60 Formal skilled craft and operative training and study (specify) _____

61 Other (specify) _____

70 Not applicable - no post high school training

cc 10–11

11. Do you feel that a person doing your work would require special skills or knowledge?

Circle your answer. 1. Yes 2. No cc 12

If you answered 'Yes', briefly list these skills or knowledges.

_____ cc 13–14

_____ cc 15–16

_____ cc 17–18

12. If your answer to Item 11 was 'Yes', circle the number of the most important source of these special skills or knowledges.

1. Self study
2. Practical experience on the job
3. Formal training programs or courses (e.g., employer sponsored courses, college courses, professional society sponsored courses) cc 19

13. Have you completed any formal classroom training programs or courses in solar or solar related energy?

Circle your answer. 1. Yes 2. No cc 20

course by placing a check (√) in the appropriate column.

TITLE OF TRAINING PROGRAM OR COURSE		PROGRAM DURATION IN HOURS	WHO CONDUCTED THE COURSE? (Check One For Each Course) 1. EMPLOYER	2. VOCATIONAL OR TRADE SCHOOL	3. COLLEGE OR UNIVERSITY	4. PROFESSIONAL OR TECHNICAL SOCIETY	5. OTHER (SPECIFY)	6. OTHER (SPECIFY)	
21–22	23–24								cc 25
26–27	28–29								cc 30
31–32	33–34								cc 35
36–37	38–39								cc 40
41–42	43–44								cc 45
46–47	48–49								cc 50
51–52	53–54								cc 55
56–57	58–59								cc 60

16. If your answer to question 15 was 'Yes', briefly describe the professional certification or journeyman licensing which you have that is related to the work you do in solar energy.

_____

_____

_____ cc 62–63

17. What percent (to the nearest 10%) of your work time in solar or solar related energy do you estimate is spent in:

Work in which you feel you need more education and training than you have. cc 64–66	
Work well suited to your education and training. cc 67–69	
Work requiring less education and training than you have. cc 70–72	
Your answer to this question should add up to 100% TOTAL	100%

18. If you feel you need more education and training for your work in solar energy, please describe the desired subject matter in detail:

_____

_____

_____

_____ cc 73–74

THANK YOU FOR YOUR COOPERATION

DEFINITIONS

Types of Solar Energy

Space heating and cooling: the transmission and storage of solar thermal energy using solar collectors, some transmission medium, and storage facilities. Includes passive and active residential or commercial solar heating or cooling of human, plant or animal shelters.

Solar water heating: the transmission and storage of solar thermal energy using solar collectors, heat exchangers, and some transmission medium. Includes passive and active residential or commercial solar water heating and swimming pool heating.

Industrial process heat: the transmission of solar thermal energy for various industrial applications using solar collectors and some transmission medium. Includes crop dryers.

Thermal power: the use of concentrating solar collectors, heat absorbers, boilers, and heat exchangers, etc., to generate electricity. Includes irrigation systems.

Ocean thermal conversion: the generation of electricity by use of the temperature difference between surface and deep water.

Photovoltaic conversion: the generation of electricity by allowing sunlight to fall upon two dissimilar substances in what is commonly called a solar cell.

Wind conversion: the generation of energy through the use of machines consisting of revolving blades or airfoils.

Biomass conversion: the cultivation and chemical processing (via fermentation, pyrolysis, or combustion) of terrestrial or aquatic plants for the purpose of creating direct energy, fuels, or chemical feedstocks.

Phases of Solar and Solar-Related Energy Work

Research and Development: theoretical or experimental investigations directed toward the acquisition of new or fuller scientific knowledge of the subject studied, or systematic application of scientific knowledge directed toward the creation of new or substantially improved equipment, processes, procedures, and techniques in any area of solar energy; or prototype design and engineering of solar energy hardware components and/or systems.

Manufacturing: the mechanical or chemical transformation of materials into components designed specifically for application in a solar energy system; also, the assembly of solar components and other materials into solar energy systems.

Marketing and Distribution: the process of estimating the demand for a product, promoting the product, transporting the product and selling the product.

Installation and Maintenance: specialized activities, such as plumbing, electrical wiring, metal and glass working, etc., required to emplace or prepare solar energy components and/or systems for actual operation; also, specialized repair services required to locate or correct failures in components and/or solar energy systems.

Other Commercial Activities: customer design, routine product testing and quality control, engineering and consulting services to licensees, experimental work needed for patent litigation, etc.

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

Dear Sir or Madame:

The United States Department of Energy (DOE) is planning to conduct a survey of employment in the field of solar energy. If your organization is engaged in work in any field of solar energy (including space heating and cooling, solar water heating, industrial process heat, thermal power, ocean thermal conversion, photovoltaic conversion, wind conversion, or biomass conversion) we would like you to participate in the survey. In order for us to know whether or not your organization's participation is appropriate, would you please answer five simple questions on the reverse side of this letter, and return it to us as soon as possible?

If you agree to participate, you will be provided with the results of the survey, and a report which will indicate projected manpower requirements in industry, as well as in each area of solar energy.

If your organization is not engaged in work in any field of solar energy, just check here ☐, and return this letter to us in the envelope provided. You need not complete the questions on the reverse side, and no further contact will be made. It is important for us to receive a response from each organization contacted in order to avoid further unnecessary contacts.

Answering the questions is voluntary, however, your cooperation is important in planning and conducting the survey. Responses to the questions will be combined with those of other respondents. Information furnished by individual organizations will be kept in strict confidence, and identifying information will not be reported or disclosed.

Return of this questionnaire gives us consent to use the information provided only for the purposes and under the conditions described above. A stamped return envelope is enclosed for your convenience.

Thank you for your cooperation.

Sincerely,

Gerard W. Levy

1. Which of the following types of solar energy apply to your organization? (See the attached definitions.) Place a check mark (✓) next to all that apply.

Space Heating and Cooling	____	(cc 7)
Solar Water Heating	____	
Industrial Process Heat	____	
Thermal Power	____	
Ocean Thermal Conversion	____	
Photovoltaic Conversion	____	
Wind Conversion	____	
Biomass Conversion	____	
Other (specify)_____	____	(cc 15)

If your organization is not engaged in work in any type of solar energy, check here [ ] . You need not complete the remaining questions and further contact will not be made.

2. What is the total number of employees in your establishment? (Include all personnel whether or not engaged in solar or solar related energy activities). . . . . [ ] (cc 16-19)

3. Of the total number of employees reported above, how many are working in solar or solar related energy activites?. . . . . [ ] (cc 20-23)

4. Would you be willing to answer a more detailed questionnaire about your organization's work and jobs in solar energy which might take 30-45 minutes of your time? (cc 24)

Yes ____

No ____

5. If you are not the appropriate person in your organization to contact for more detailed information, to whom should the more detailed questionnaire be addressed?

NAME_____

TITLE_____

ADDRESS_____

CITY, STATE, ZIP CODE_____

AREA CODE, PHONE NO. (_____)_____

THANK YOU FOR YOUR COOPERATION

DEFINITIONS

Types of Solar Energy

Space heating and cooling: the transmission and storage of solar thermal energy using solar collectors, some transmission medium, and storage facilities. Includes passive and active residential or commercial solar heating or cooling of human, plant or animal shelters.

Solar water heating: the transmission and storage of solar thermal energy using solar collectors, heat exchangers, and some transmission medium. Includes passive and active residential or commercial solar water heating and swimming pool heating.

Industrial process heat: the transmission of solar thermal energy for various industrial applications using solar collectors and some transmission medium. Includes crop dryers.

Thermal power: the use of concentrating solar collectors, heat absorbers, boilers, and heat exchangers, etc. to generate electricity. Includes irrigation systems.

Ocean thermal conversion: the generation of electricity by use of the temperature difference between surface and deep water.

Photovoltaic conversion: the generation of electricity by allowing sunlight to fall upon two dissimiliar substances in what is commonly called a solar cell.

Wind conversion: the generation of energy through the use of machines consisting of revolving blades or airfoils.

Biomass conversion: the cultivation and chemical processing (via fermentation, pyrolysis, or combusion) of terrestrial or aquatic plants for the purpose of creating direct energy, fuels, or chemical feedstocks.

Battelle Cover Letter to Group 2 Employers, Explaining Employer and Employee Questionnaires

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

Dear Sir or Madam:

Thank you for responding to our initial inquiry concerning solar or solar related energy. At that time you indicated a willingness to complete a more detailed questionnaire. The enclosed questionnaire is designed to gather the information needed to characterize present manpower utilization in solar and solar related energy areas and to project and characterize future manpower needs. Participation in the survey is voluntary; however, your cooperation in completing and returning this questionnaire will be of great usefulness in planning for the orderly development of the solar energy field.

Your response to the questionnaire will be combined with those of other reporting organizations. Information furnished by individual organizations will not be reported or disclosed. Averages and other statistical measures will be used to characterize manpower requirements in solar energy. Your organization's responses to the questionnaire will be kept in complete confidence by Battelle and identifying information will not be released to DOE or any other party.

Please return the completed questionnaire within two weeks. A stamped return envelope is enclosed for your convenience. Return of the questionnaire will give Battelle's Columbus Laboratories consent to use the information which you have provided only for the purposes and under the conditions described above.

I am soliciting your further support to obtain more detailed data on the characteristics of persons working in the solar energy field. Your role in this phase of the study will be to select a sample of employees who will receive a survey form on their work and experience, and to forward the enclosed material to the person or persons selected. As with the Employer Form enclosed, employee responses will be anonymous. Furthermore, no where in our report will replies from your employees be associated with your organization.

Employees selected are to send their forms directly to Battelle; therefore, you will not be responsible for gathering and returning any material. In the event that forms are not returned by employees, we ask that you distribute follow-up letters to the employees selected.

Instructions for sampling employees and distributing materials are enclosed along with the appropriate number of survey packages. I hope that after reviewing the instructions you will lend your continued support to this study.

If you have any questions about the study or the questionnaire, please call Ms. Sandy Newman at Battelle Laboratories, collect, (614) 424-5646.

Thank you again for your cooperation.

Sincerely,

Girard W. Levy

Girard W. Levy
Project Director

GL:kc

Battelle Cover Letter
Used in Follow Up

Battelle
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-7434
Telex 24-5454

Dear Sir or Madam:

The United States Department of Energy (DOE) has initiated a survey to assess present employment and utilization of solar energy manpower. Battelle Columbus Laboratories is conducting the survey for DOE. Several weeks ago you were sent a questionnaire requesting information on your activities in solar or solar related energy. The information sought is needed to describe the current and future manpower needs in the solar energy field.

The number of organizations involved in this field is small, and it is therefore important that we obtain your input, which has not arrived at this writing. Even if your organization is not involved in solar or solar related energy activities, it is essential for us to have that information.

Would you please take just a few minutes to complete and return the enclosed questionnaire (a duplicate of the original questionnaire)? A business reply envelope is enclosed for your convenience. If this request for information should be directed to another person in your organization, please forward this letter and form to him/her. All responses will be kept confidential.

If you have any questions concerning this study or completion of the questionnaire, please call collect: Ms. Sandy Newman (614) 424-5646. Thank you for your cooperation.

Sincerely,

Girard W. Levy

Girard W. Levy
Project Director

GL:kc

APPENDIX B

RESPONSE RATE, ESTABLISHMENT POPULATION, AND NONRESPONSE BIAS

APPENDIX B

RESPONSE RATE, ESTABLISHMENT POPULATION, AND NONRESPONSE BIAS

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APPENDIX B

RESPONSE RATE, ESTABLISHMENT POPULATION, AND NONRESPONSE BIAS

This appendix contains additional details on the survey response rate, estimation of the establishment population, and analyses of possible nonresponse bias.

Response Rate

The sampling frame for establishments consisted of 2849 employers. This number was reduced by 292 establishments due to mail returned undeliverable and no current telephone listings for resend or telephone contact. A total of 1230 establishments did not respond to the mail survey. Thirteen establishments responded, but refused to provide any information concerning their solar energy activities or employment. A total of 1314 establishment responses was received, representing 46 percent of the establishments in the sampling frame, and 51 percent of the establishments contacted. Of the 1314 respondents, 285 reported they were not engaged in any type of solar energy work. A total of 466 establishments completed the short screening form only, and 563 completed the longer employer questionnaire. It should be noted that some respondents did not answer every question in the questionnaire.

Table B-1 presents a complete analysis of the response rate, including a breakdown for Group 1 and Group 2. An overall response rate of approximately 64 percent was achieved for the Group 1 establishment sample.

A total of 1254 employee questionnaires was sent to establishments (see Table B-1). Seven establishments refused to distribute a total of 20 employee forms. Other establishments were never sent employee forms because of missing information on number of solar employees, and still other establishments may have failed to distribute forms without informing Battelle. A total of 483 employee questionnaires was returned, representing approximately

TABLE B-1. SURVEY RESPONSE RATE FOR EMPLOYER AND EMPLOYEE QUESTIONNAIRES, 1978

	Sampling Frame	Sample Size	Presumed Contacts (Not Returned)		Refusals			Responses									Total		
								No Solar			Long Form			Sh					
	N	N_a	N_b	$\%_a$	N	$\%_a$	$\%_b$	N	$\%_a$	$\%_b$	N	$\%_a$	$\%_b$	N			N	$\%_a$	$\%_b$
Employers, total	2849	2849	2557	89.8	13	0.5	0.5	285	10.0	11.1	563	19.8	22.0	466				46.1	51.4
Group 1		968	864	89.3	6	0.6	0.7	123	12.7	14.2	354	36.6	41.0	72				56.7	63.5
Group 2		1881	1693	90.0	7	0.4	0.4	162	8.6	9.6	209	11.1	12.3	394	2		5	40.7	45.2
Nonrespondents, Group 1	(309)	(162)	(91)	56.2	(4)	2.5	4.4	(30)	18.5	33.0	--	--	--	(57)	35.2	62.6	(87)	53.7	95.6
Employees, total		1254	--	--	20	1.6	--	3	0.2	--	480	38.3	--	--	--	--	483	38.5	--

a - identifies percentages based on the sample size (N_a)

b - identifies percentages based on the number of presumed contacts, i.e., mail not returned (N_b)

38 percent of the forms sent. Of the employee questionnaires returned, 3 employees were not engaged in solar or solar related energy work activities.

Also shown in Table B-1 is the response rate for the Group 1 nonrespondent follow-up sample of establishments.

Estimates of the Establishment Population

The estimated number of establishments in the sampling frame was computed based on the 2557 presumed contacts out of the 2849 establishment names in the sampling frame. The one standard error estimate is 2557 $\pm$ 16 establishments. Not all of these establishments were engaged in solar energy work. An estimate of the number of establishments engaged in solar energy work was obtained by using the proportion of Group 1 nonrespondents found to be engaged in solar energy work (.67) and applying this proportion to the establishments in the sampling frame which had not supplied any information concerning whether or not they were engaged in solar energy work (1139). The number of establishments known to be engaged in solar energy work based on their response to the questionnaires and telephone calls (1103) was then added to the estimate. The two-standard error estimate for the number of establishments in the sampling frame engaged in solar energy work in 1978 is 1867 $\pm$ 65. This estimate was used to compute the estimated total employment in solar energy in subsequent analyses.

Analysis of Possible Nonresponse Bias

Three types of analyses were conducted to detect possible nonresponse bias. In general, the results of these analyses were negative, indicating little or no difference between respondent and nonrespondent establishments.

The first analysis involved a comparison of respondent and all nonrespondent establishments in terms of geographic distribution. Table B-2 presents the geographic distribution of all establishments in the sampling frame. The distribution of respondents and nonrespondents was not statistically different at the 5 percent level of confidence.

TABLE B-2. GEOGRAPHICAL DISTRIBUTION OF ESTABLISHMENTS, 1978

Federal Region	Respondent Establishments N	%	Nonrespondent Establishments N	%	Total Sampling Frame N	%
I	77	13.7	323	14.1	400	14.0
II	63	11.2	246	10.8	309	10.8
III	71	12.6	298	13.0	369	13.0
IV	52	9.2	277	12.1	329	11.5
V	72	12.8	255	11.2	327	11.5
VI	41	7.3	159	7.0	200	7.0
VII	20	3.6	73	3.2	93	3.3
VIII	35	6.2	145	6.3	180	6.3
IX	115	20.4	450	19.7	565	19.8
X	17	3.0	60	2.6	77	2.7
Total	563	100.0	2286	100.0	2849	100.0

$X^2 = 5.13$, df = 9, $p > .05$

The second analysis involved a comparison of respondents with the sample of nonrespondents contacted by telephone in terms of type of organization, geographic region, type of solar energy, total employment, solar employment, and percentage of solar employment. No statistically significant differences at the 5 percent level of confidence were found between respondents and the sample of nonrespondents in terms of type of organization, or geographic region.

Table B-3 presents the means and standard deviations for the respondents and the nonrespondent sample for total employment, solar employment and percent solar employment. No significant differences in means were found at the 5 percent level of confidence.

A significant difference between respondents and the sample of nonrespondents was found for the types of solar energy in which the establishments worked. Table B-4 presents a comparison between respondents and the nonrespondent sample in terms of types of solar energy. Respondents indicated that they were engaged in work in space heating and cooling, water heating, and industrial process heat more frequently than nonrespondents. Respondents were engaged in the "other" category of solar energy types less frequently than nonrespondents. In addition, nonrespondent establishments reported fewer different types of solar energy. These differences can be attributed to the contact procedure and necessary format differences in the question for the two groups. The respondents checked all the types of solar energy applicable to their establishment on a printed questionnaire. They were also supplied with definitions. The nonrespondents were read the list of types of solar energy over the phone and indicated those applicable. Nonrespondents may have listened to the list and responded only to the primary type of solar energy they were engaged in. The difference in number of types reported may completely explain the differences in type of solar energy work engaged in.

The third analysis involved a comparison of Group 1 and Group 2 respondents in terms of type of organization, geographic region, industry group, percent solar R&D work, total employment, solar employment, percent solar employment, and type of solar work. There were no significant differences at the 5 percent level of confidence between the two groups on any of these variables. Thus, the method of contact and extent of follow up did not make a difference in the kind or size of responding establishments.

TABLE B-3. COMPARISONS BETWEEN RESPONDENTS AND NONRESPONDENTS ON EMPLOYMENT VARIABLES, 1978

Variable	Respondents	Nonrespondents
Total Employment		
Mean	885.3	646.9*
Standard Deviation	2337.2	1821.4
Number of Establishments	548	55
Solar Employment		
Mean	11.6	22.9*
Standard Deviation	27.4	60.9
Number of Establishments	550	57
Percent Solar Employment		
Mean	43.0	48.6*
Standard Deviation	41.5	44.1
Number of Establishments	541	55

* Differences between means were not significant at the 5 percent level of confidence.

TABLE B-4. COMPARISONS BETWEEN RESPONDENTS AND NONRESPONDENTS ON TYPES OF SOLAR ENERGY APPLICABLE TO ESTABLISHMENT, 1978

Type of Solar Energy	Respondents (N=549) N	%	Nonrespondents (N=57) N	%
Space Heating and Cooling	454	82.7	35	61.4*
Water Heating	440	80.1	33	57.9*
Industrial Process Heat	206	37.5	6	10.5*
Thermal Power	103	18.8	10	17.5
Ocean Thermal Conversion	52	9.5	6	10.5
Photovoltaic Conversion	146	26.6	9	15.8
Wind Conversion	136	24.8	8	14.0
Biomass Conversion	98	17.9	7	12.3
Other	46	8.4	15	26.3*

* Differences were significant beyond the 5 percent level of confidence.

Based on these results, the two groups were combined in all subsequent analyses.

APPENDIX C

DETAILED TABULATIONS

APPENDIX C

DETAILED TABULATIONS

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LIST OF TABLES (Cont'd.)

LIST OF TABLES (Cont'd.)

TABLE C-1. PRINCIPAL SOLAR RELATED PRODUCTS AND SERVICES PROVIDED BY RESPONDENTS, 1978

Products/Services	Percent of Respondents (N=547)
Space Heating and Cooling	
Space heating and cooling, general	0.5
Solar heating and cooling systems	1.5
Water heating systems	0.4
Solar assisted heat pumps	1.8
Solar driven heat pumps	0.2
Water Heating	
Water heating, general	0.7
Residential water heating systems	3.1
Industrial Process Heat	
Industrial process heat, general	0.2
Thermal Power	
Thermal power, general	0.9
Stirling cycle power systems	0.2
Ocean Thermal Conversion	
Turbines	0.2
Heat exchangers for OTEC	0.2
Photovoltaic Conversion	
Photovoltaic conversion, general	2.0
Integrated photovoltaic power systems	0.4
Photovoltaic concentrator systems	0.4
Wind Conversion	
Wind conversion, general	0.4
WECS rotor blades	0.2
Vertical axis wind turbines	0.2
Wind turbine generators	0.9
Biomass Conversion	
Biomass conversion, general	0.4
Fireplace heat extractor grates	0.2
Anaerobic digestion systems	0.2
Solar wood heating and cooling systems	0.2
Total Energy System	
Total energy system, general	1.6

TABLE C-1. (Continued)

Products/Services	Percent of Respondents (N=547)
Collectors	
Collectors, general	0.7
Flat plate collectors, air type	3.1
Flat plate collectors, liquid type	1.8
Flat plate collectors, both types or unspecified	14.4
Concentrating collectors	2.6
Non-imaging concentrating collectors	0.5
Swimming pool collectors	1.1
Heliostats	0.2
Evacuated tube collectors	0.5
Collectors, other	0.7
Collector Components	
Collector components, general	0.5
Absorbers, liquid	1.3
Absorbers, air	0.4
Manifolds/headers	0.2
Insulation	0.5
Covers	1.1
Coatings	0.7
Controls	0.4
Heat transfer fluids	0.5
Heat Exchangers	
Heat exchangers, general	0.7
Air	1.6
Water/air	0.2
Heat pipe systems	0.2
Controls and Indicators	
Temperature controls	1.3
Control equipment	1.1
Pump controller package units	0.7
Control systems	1.8
Solar tracking/measuring devices	0.9
Electronic sensors	0.5
Circulating Pumps	
Circulating pumps, general	0.5

TABLE C-1. (Continued)

Products/Services	Percent of Respondents (N=547)
Energy Storage Systems	
Solar storage/distribution systems	0.2
Chemical storage cycles	0.2
Storage tanks	1.1
Thermal storage	0.2
Rock storage	0.4
Other Products	
Solar water purifiers	0.2
Solar powered radios and charge boxes	0.2
Black/white venetian blinds	0.2
Solar energy conversion systems	0.2
Services	
Contractual/grant support and administration	3.5
Research and development	26.1
Architectural and engineering	19.0
Active design	2.0
Passive design	5.7
Installation	4.2
Distribution/marketing	8.4
Information/publications	7.9
Education/training	7.1
Other services	3.8

TABLE C-2. TYPE OF ORGANIZATION ENGAGED IN SOLAR ENERGY BY PRIMARY TYPE OF SOLAR ENERGY, 1978

	Primary Type of Solar Energy																			
	Space Heating and Cooling		Water Heating		Industrial Process Heat		Thermal Power		Ocean Thermal Conversion		Photovoltaic Conversion		Wind Conversion		Biomass Conversion		Other	
Type of Organization	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Private Industry	146	63.2	94	68.6	5	55.6	8	61.5	10	76.9	23	76.7	9	60.0	3	23.1	8	44.4
Construction Contractor	24	10.4	10	7.3	1	11.1	1	7.7	0	0.0	1	3.3	0	0.0	1	7.7	2	11.1
Public Utility	12	5.2	15	10.9	0	0.0	3	23.1	0	0.0	0	0.0	3	20.0	0	0.0	0	0.0
Federal Government	2	0.9	0	0.0	0	0.0	1	7.7	0	0.0	1	3.3	1	6.7	0	0.0	0	0.0
State or Local Government	12	5.2	8	5.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	15.4	0	0.0
Nonprofit Organization	16	6.9	4	2.9	1	11.1	0	0.0	1	7.7	1	3.3	0	0.0	2	15.4	5	27.8
Educational Institution	17	7.4	5	3.6	2	22.2	0	0.0	2	15.4	4	13.3	2	13.3	5	38.5	2	11.1
Other	2	0.9	1	0.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	5.6
Total	231	100.0	137	100.0	9	100.0	13	100.0	13	100.0	30	100.0	15	100.0	13	100.0	18	100.0

TABLE C-3. TYPE OF ORGANIZATION ENGAGED IN SOLAR ENERGY BY TYPE OF SOLAR WORK, 1978

Type of Organization	Type of Solar Work: Manufacturing Flat Plate Collectors N	%	Manufacturing Other Products N	%	Installation N	%	R&D Services N	%	Architectural and Engineering Services N	%	Other Services N	%
Private Industry	73	100.0	94	98.9	26	38.8	30	24.6	85	85.9	32	36.4
Construction Contractor	0	0.0	0	0.0	41	61.2	0	0.0	0	0.0	4	4.5
Public Utility	0	0.0	0	0.0	0	0.0	25	20.5	3	3.0	6	6.8
Federal Government	0	0.0	0	0.0	0	0.0	5	4.1	1	1.0	3	3.4
State or Local Government	0	0.0	0	0.0	0	0.0	6	4.9	2	2.0	22	25.0
Nonprofit Organization	0	0.0	0	0.0	0	0.0	19	15.6	5	5.1	13	14.8
Educational Institution	0	0.0	0	0.0	0	0.0	36	29.5	3	3.0	6	6.8
Other	0	0.0	1	1.1	0	0.0	1	0.8	0	0.0	2	2.3
Total	73	100.0	95	100.0	67	100.0	122	100.0	99	100.0	88	100.0

TABLE C-4. INDUSTRIAL CLASSIFICATION OF ESTABLISHMENT BY PRIMARY TYPE OF SOLAR ENERGY, 1978

Industry	Primary Type of Solar Energy																	
	Space Heating and Cooling		Water Heating		Industrial Process Heat		Thermal Power		Ocean Thermal Conversion		Photovoltaic Conversion		Wind Conversion		Biomass Conversion		Other	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Durable Goods Manufacturing	53	22.9	50	36.8	1	11.1	4	33.3	1	7.7	11	36.7	6	40.0	2	15.4	7	38.9
Construction	18	7.8	19	14.0	1	11.1	0	0.0	0	0.0	0	0.0	0	0.0	1	7.7	1	5.6
Nondurable Goods Manufacturing	10	4.3	7	5.1	2	22.2	1	8.3	0	0.0	5	16.7	0	0.0	0	0.0	0	0.0
Transportation, Communications and Public Utilities	15	6.5	16	11.8	0	0.0	3	25.0	0	0.0	1	3.3	3	20.0	0	0.0	0	0.0
Wholesale or Retail Trade	13	5.6	17	12.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	5.6
Educational Services	23	10.0	7	5.1	2	22.2	0	0.0	2	15.4	3	10.0	2	13.3	5	38.5	3	16.7
Engineering and Architectural Services	63	27.3	10	7.4	1	11.1	2	16.7	5	38.5	2	6.7	0	0.0	1	7.7	0	0.0
Research Services	21	9.1	1	.7	2	22.2	2	16.7	4	30.8	7	23.3	4	26.7	2	15.4	4	22.2
Other Services and Public Administration	15	6.5	9	6.6	0	0.0	0	0.0	1	7.7	1	3.3	0	0.0	2	15.4	2	11.1
Total	231	100.0	136	100.0	9	100.0	12	100.0	13	100.0	30	100.0	15	100.0	13	100.0	18	100.0

TABLE C-5. INDUSTRIAL CLASSIFICATION OF ESTABLISHMENTS BY TYPE OF SOLAR WORK, 1978

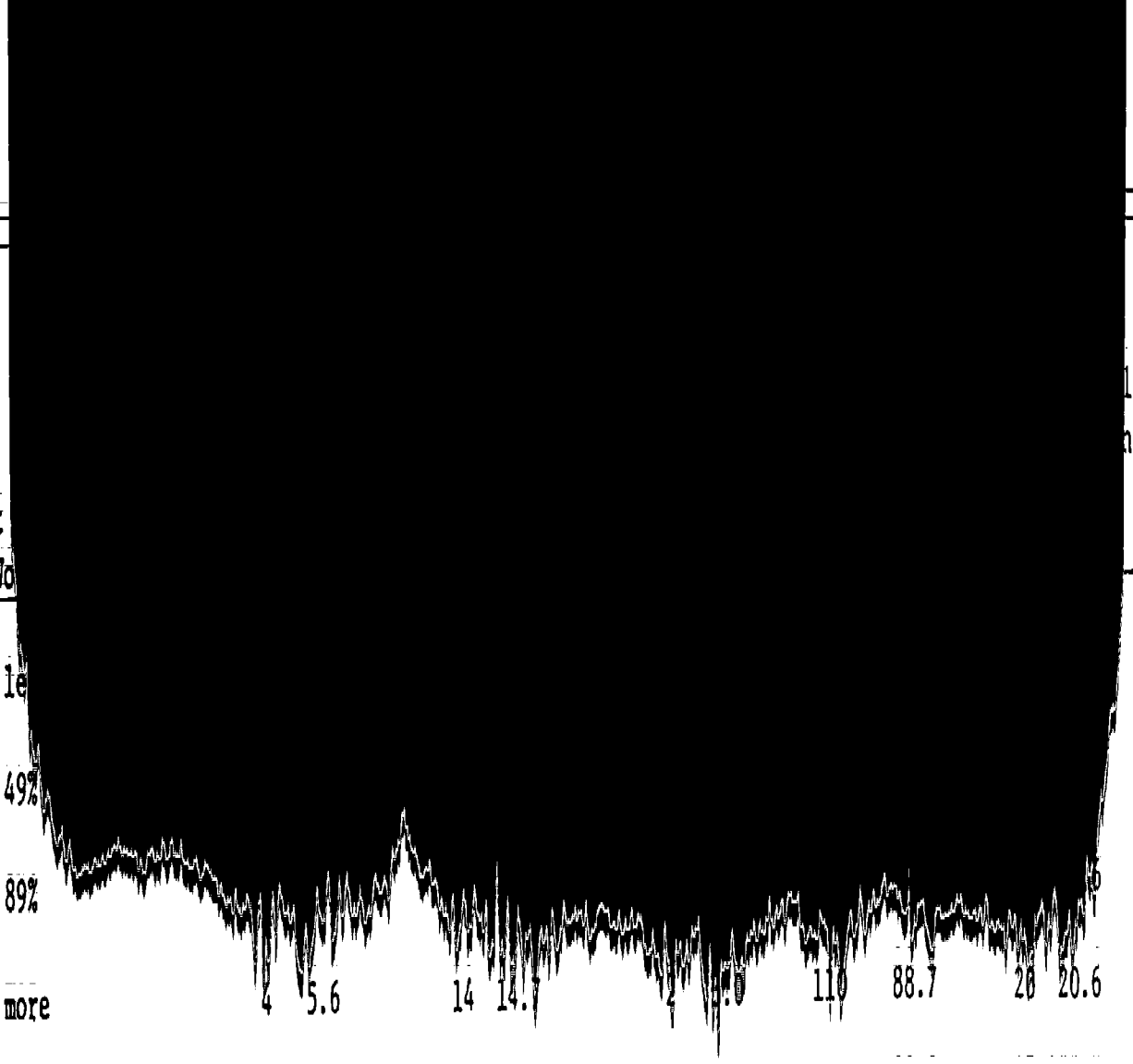
Industry	Type of Solar Work: Manufacturing Flat Plate Collectors N	%	Manufacturing Other Products N	%	Installation N	%	R&D Services N	%	Architectural and Engineering Services N	%	Other Services N	%
Durable Goods Manufacturing	66	90.4	72	79.1	9	13.4	1	0.8	0	0.0	1	1.1
Construction	0	0.0	0	0.0	45	67.2	0	0.0	0	0.0	0	0.0
Nondurable Goods Manufacturing	7	9.6	19	20.9	0	0.0	2	1.6	0	0.0	0	0.0
Transportation, Communication and Public Utilities	0	0.0	0	0.0	1	1.5	28	22.8	3	3.0	7	8.0
Wholesale or Retail Trade	0	0.0	0	0.0	4	6.0	0	0.0	2	2.0	29	33.0
Educational Services	0	0.0	0	0.0	0	0.0	36	29.3	2	2.0	19	21.6
Engineering and Architectural Services	0	0.0	0	0.0	8	11.9	1	0.8	84	84.8	0	0.0
Research Services	0	0.0	0	0.0	0	0.0	44	35.8	5	5.1	5	5.7
Other Services and Public Administration	0	0.0	0	0.0	0	0.0	11	8.9	3	3.0	27	30.7
Total	73	100.0	91	100.0	67	100.0	123	100.0	99	100.0	88	100.0

TABLE C-6. PERCENTAGE OF SOLAR WORK IN R&D BY INDUSTRIAL CLASSIFICATION OF ESTABLISHMENT, 1978

Percent Solar R&D Work	Industry															
	Durable Goods Manufacturing		Construction		Nondurable Goods Manufacturing		Transportation, Communication and Public Utilities		Wholesale or Retail Trade		Educational Services		Engineering and Architectural Services		Research Services		Other Services and Public Administration	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
10% or less	57	38.5	26	57.8	7	25.9	4	9.8	24	68.6	3	5.0	37	40.7	0	0.0	7	18.9
11% to 49%	45	30.4	13	28.9	7	25.9	3	7.3	9	25.7	4	6.7	26	28.6	2	3.7	2	5.4
50% to 89%	31	20.9	5	11.1	7	25.9	6	14.6	1	2.9	5	8.3	13	14.3	7	13.0	5	13.5
90% or more	15	10.1	1	2.2	6	22.2	28	68.3	1	2.9	48	80.0	15	16.5	45	83.3	23	62.2
Total	148	100.0	45	100.0	27	100.0	41	100.0	35	100.0	60	100.0	91	100.0	54	100.0	37	100.0

TABLE C-7. PERCENTAGE OF SOLAR WORK IN R&D BY PRIMARY TYPE OF SOLAR ENERGY, 1978

Percent Solar R&D Work	Primary Type of Solar Energy																	
	Space Heating and Cooling		Water Heating		Industrial Process Heat		Thermal Power		Ocean Thermal Conversion		Photovoltaic Conversion		Con			ss sion	Other	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
10% or less	76	32.9	64	47.1	2	22.2	0	0.0	1	7.7	2	6.9	2	13		0.0	4	23.5
11% to 49%	57	24.7	36	26.5	2	22.2	0	0.0	0	0.0	5	17.2	1	6.7	1	7.7	2	11.8
50% to 89%	34	14.7	15	11.0	1	11.1	1	7.7	0	0.0	7	24.1	3	20.0	1	7.7	6	35.3
90% or more	64	27.7	21	15.4	4	44.4	12	92.3	12	92.3	15	51.7	9	60.0	11	84.6	5	29.4
Total	231	100.0	136	100.0	9	100.0	13	100.0	13	100.0	29	100.0	15	100.0	13	100.0	17	100.0



Percent R&D Wo										Other Services	
										N	%
10% or le										32	40.0
11% to 49%										13	16.2
50% to 89%										9	11.2
90% or more	4	5.6	14	14.7	2	3.0	110	88.7	20 20.6	26	32.5
Total	71	100.0	95	100.0	66	100.0	124	100.0	97 100.0	80	100.0

TABLE C-9. ESTABLISHMENT SIZE BY PRIMARY TYPE OF SOLAR ENERGY, 1978

	Primary Type of Solar Energy																	
	Space Heating and Cooling		Water Heating		Industrial Process Heat		Thermal Power		Ocean Thermal Conversion		Photovoltaic Conversion		Wind Conversion		Biomass Conversion		Other	
Total Employment	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1 - 2	25	11.0	13	9.7	0	0.0	0	0.0	2	15.4	0	0.0	1	6.7	0	0.0	2	12.5
3 - 5	29	12.8	27	20.1	0	0.0	2	18.2	0	0.0	2	6.7	0	0.0	1	7.7	2	12.5
6 - 10	40	17.6	21	15.7	0	0.0	0	0.0	0	0.0	2	6.7	2	13.3	2	15.4	3	18.8
11 - 20	29	12.8	22	16.4	1	11.1	0	0.0	2	15.4	1	3.3	3	20.0	1	7.7	1	6.3
21 - 40	22	9.7	12	9.0	2	22.2	0	0.0	2	15.4	2	6.7	1	6.7	1	7.7	2	12.5
41 - 100	28	12.3	11	8.2	1	11.1	0	0.0	0	0.0	4	13.3	1	6.7	2	15.4	4	25.0
101 - 400	13	5.7	5	3.7	3	33.3	2	18.2	2	15.4	10	33.3	1	6.7	2	15.4	1	6.3
401 - 3000	19	8.4	13	9.7	2	22.2	3	27.3	3	23.1	6	20.0	3	20.0	4	30.8	0	0.0
Greater than 3000	22	9.7	10	7.5	0	0.0	4	36.4	2	15.4	3	10.0	3	20.0	0	0.0	1	6.3
Total	227	100.0	134	100.0	9	100.0	11	100.0	13	100.0	30	100.0	15	100.0	13	100.0	16	100.0

TABLE C-10. PERCENTAGE SOLAR EMPLOYMENT BY TYPE OF ORGANIZATION, 1978

Percent Solar Employment	Type of Organization																	
	Private Industry		Construction Contractor		Public Utility		Federal Government		State or Local Government		Nonprofit Organization		Educational Institution		Other	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Less than 4%	64	19.4	1	2.1	33	91.7	6	66.7	6	19.4	12	32.4	21	46.7	1	25.0
5% to 24%	53	16.1	10	22.7	1	2.8	1	11.1	21	67.7	15	40.5	17	37.8	1	25.0
25% to 49%	35	10.6	10	22.7	1	2.8	2	22.2	2	6.5	3	8.1	1	2.2	0	0.0
50% to 99%	49	14.8	5	11.4	0	0.0	0	0.0	2	6.5	3	8.1	4	8.9	2	50.0
100%	129	39.1	18	40.9	1	2.8	0	0.0	0	0.0	4	10.8	2	4.4	0	0.0
Total	330	100.0	44	100.0	36	100.0	9	100.0	31	100.0	37	100.0	45	100.0	4	100.0

TABLE C-11. PERCENTAGE SOLAR EMPLOYMENT BY INDUSTRIAL CLASSIFICATION OF ESTABLISHMENT, 1978

	Industry																	
Percent Solar Employment	Durable Goods Manufacturing		Construction		Nondurable Goods Manufacturing		Transportation, Communication and Public Utilities		Wholesale or Retail Trade		Educational Services		Engineering and Architectural Services		Research Services		Other Services and Public Administration	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Less than 4%	37	25.5	1	2.3	11	42.3	37	90.2	1	2.9	22	39.3	8	9.0	19	35.2	9	20.9
5% to 24%	16	11.0	10	22.7	4	15.4	2	4.9	2	5.7	19	33.9	23	25.8	18	33.3	25	58.1
25% to 49%	9	6.2	10	22.7	3	11.5	1	2.4	2	5.7	4	7.1	16	18.0	4	7.4	2	4.7
50% to 99%	22	15.2	8	18.2	4	15.4	0	0.0	6	17.1	4	7.1	12	13.5	4	7.4	5	11.6
100%	61	42.1	15	34.1	4	15.4	1	2.4	24	68.6	7	12.5	30	33.7	9	16.7	2	4.7
Total	145	100.0	44	100.0	26	100.0	41	100.0	35	100.0	56	100.0	89	100.0	54	100.0	43	100.0

TABLE C-12. PERCENTAGE SOLAR EMPLOYMENT BY PRIMARY TYPE OF SOLAR ENERGY, 1978

	Primary Type of Solar Energy																			
	Space Heating and Cooling		Water Heating		Industrial Process Heat		Thermal Power		Ocean Thermal Conversion		Photovoltaic Conversion		Wind Conversion		Biomass Conversion		Other	
Percent Solar Employment	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Less than 4%	54	23.9	26	19.4	5	55.6	6	54.5	6	46.2	13	46.4	7	46.7	6	46.2	2	12.5
5% to 24%	49	21.7	24	17.9	3	33.3	3	27.3	5	38.5	4	14.3	1	6.7	3	23.1	6	37.5
25% to 49%	27	11.9	10	7.5	1	11.1	1	9.1	0	0.0	3	10.7	3	20.0	0	0.0	1	6.3
50% to 99%	27	11.9	19	14.2	0	0.0	0	0.0	0	0.0	4	14.3	0	0.0	2	15.4	4	25.0
100%	69	30.5	55	41.0	0	0.0	1	9.1	2	15.4	4	14.3	4	26.7	2	15.4	3	18.8
Total	226	100.0	134	100.0	9	100.0	11	100.0	13	100.0	28	100.0	15	100.0	13	100.0	16	100.0

TABLE C-13. PERCENTAGE SOLAR EMPLOYMENT BY TYPE OF SOLAR WORK, 1978

Percent Solar Employment	Type of Solar Work: Manufacturing Flat Plate Collectors N	%	Manufacturing Other Products N	%	Installation N	%	R&D Services N	%	Architectural and Engineering Services N	%	Other Services N	%
Less than 4%	14	19.7	30	33.0	3	4.6	61	51.7	12	12.6	18	20.9
5% to 24%	6	8.5	13	14.3	13	20.0	34	28.8	26	27.4	24	27.9
25% to 49%	5	7.0	8	8.8	13	20.0	6	5.1	15	15.8	5	5.8
50% to 99%	10	14.1	15	16.5	10	15.4	7	5.9	13	13.7	10	11.6
100%	36	50.7	25	27.5	26	40.0	10	8.5	29	30.5	29	33.7
Total	71	100.0	91	100.0	65	100.0	118	100.0	95	100.0	86	100.0

TABLE C-14. PERCENTAGE SOLAR EMPLOYMENT BY PERCENTAGE OF SOLAR WORK IN R&D, 1978

Percent Solar Employment	Percent Solar R&D Work							
	10% or less		11% - 49%		50% to 89%		90% or more	
	N	%	N	%	N	%	N	%
Less than 4%	26	16.0	12	11.2	20	25.0	81	45.8
5% to 24%	30	18.5	15	14.0	13	16.2	56	31.6
25% to 49%	19	11.7	16	15.0	6	7.5	13	7.3
50% to 99%	22	13.6	15	14.0	16	20.0	11	6.2
100%	65	40.1	49	45.8	25	31.3	16	9.0
Total	162	100.0	107	100.0	80	100.0	177	100.0

TABLE C-15. OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT IN SOLAR ACTIVITIES -- DETAIL ON INFREQUENTLY MENTIONED OCCUPATIONS, 1978. BASED ON 518 REPORTING ESTABLISHMENTS

Occupation	Research and Development Reported N	Commercial (except Installation) Reported N	Installation Reported N	Reported Frequency of Difficult to Hire
Engineers				
Architectural	10	7	2	4
Industrial	15	9	0	1
Unspecified	457	169	14	46
Scientists				
Agricultural	14	0	0	0
Atmospheric	15	1	0	4
Earth	3	0	0	1
Marine	11	1	0	0
Mathematicians	6	1	0	0
Unspecified	200	18	0	13
Other Professionals				
Administrative	16	20	0	2
Urban Planners	14	2	0	0
Unspecified	146	76	4	8
Technicians				
Agricultural	3	0	0	0
Draftsman	12	9	3	5
Industrial	2	4	0	1
Mathematical	1	0	0	0
Unspecified	245	92	5	15

TABLE C-15. (Continued)

Occupation	Research and Development Reported N	Commercial (except Installation) Reported N	Installation Reported N	Reported Frequency o Difficult to Hire
Skilled Crafts and Operatives				
Asbestos and Insulation Workers	1	2	2	1
Cement Finishers	C	0	2	0
Electricians	6	14	2	1
Glaziers	0	2	0	0
Heat Treaters	0	4	0	0
Metal Molders	1	4	0	0
Metal Platers	2	10	0	2
Opticians	6	6	1	2
Pattern Makers	0	1	0	0
Precision Machine Operatives	3	1	0	1
Riveters	2	9	2	0
Rollers	1	5	1	0
Roofers	0	0	2	0
Solderers	5	20	2	0
Structural Metal Craftsmen	2	13	0	0
Tool and Die Makers	1	8	1	0
cified	127	419	37	13

TABLE C-16. OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT IN SOLAR SPACE HEATING AND COOLING/WATER HEATING, 1978. BASED ON 346 ESTABLISHMENTS

Occupational Group	Research and Development			Commercial			Total		
	Reported		Estimated	Reported		Estimated	Reported		Estimated
	N	%[a]	N[b]	N	%[a]	N[b]	N	%[a]	N[b]
Engineers	663	42	2,500	346	17	1,300	1,009	28	3,700
Scientists	161	10	600	32	2	100	193	5	700
Other Professionals	260	16	1,000	288	14	1,000	548	15	2,000
Technicians	165	10	600	156	8	600	321	9	1,200
Skilled Crafts and Operatives	115	7	400	586	29	2,100	701	19	2,500
Clerical and Unskilled Workers	160	10	600	592	29	2,200	752	21	2,800
No Occupation Given	52	3	--	22	1	--	74	2	--
Total, All Groups	1,576	100	5,700	2,022	100	7,300	3,598	100	13,000

a Total may not add to 100% due to rounding.

b Includes allocation of "No Occupation Given" category/Detail may not add to total due to rounding.

TABLE C-17. OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT IN SOLAR INDUSTRIAL PROCESS HEAT, 1978. BASED ON 8 ESTABLISHMENTS

Occupational Group	Research and Development			Commercial					
	Reported		Estimated	Reported		Estimated	R		Estimated
	N	%[a]	N[b]	N	%[a]	N[b]			N[b]
Engineers	24	59	100	11	44	c			100
Scientists	8	20	c	1	4	c			c
Other Professionals	3	7	c	6	24	c			c
Technicians	3	7	c	4	16	c			c
Skilled Crafts and Operatives	1	2	c	1	4	c	2	3	c
Clerical and Unskilled Workers	2	5	c	2	8	c	4	6	c
No Occupation Given	0	0	--	0	0	--	0	0	--
Total, All Groups	41	100	100	25	100	100	66	100	200

a Total may not add to 100% due to rounding.

b Includes allocation of "No Occupation Given" category/Detail may not add to total due to rounding.

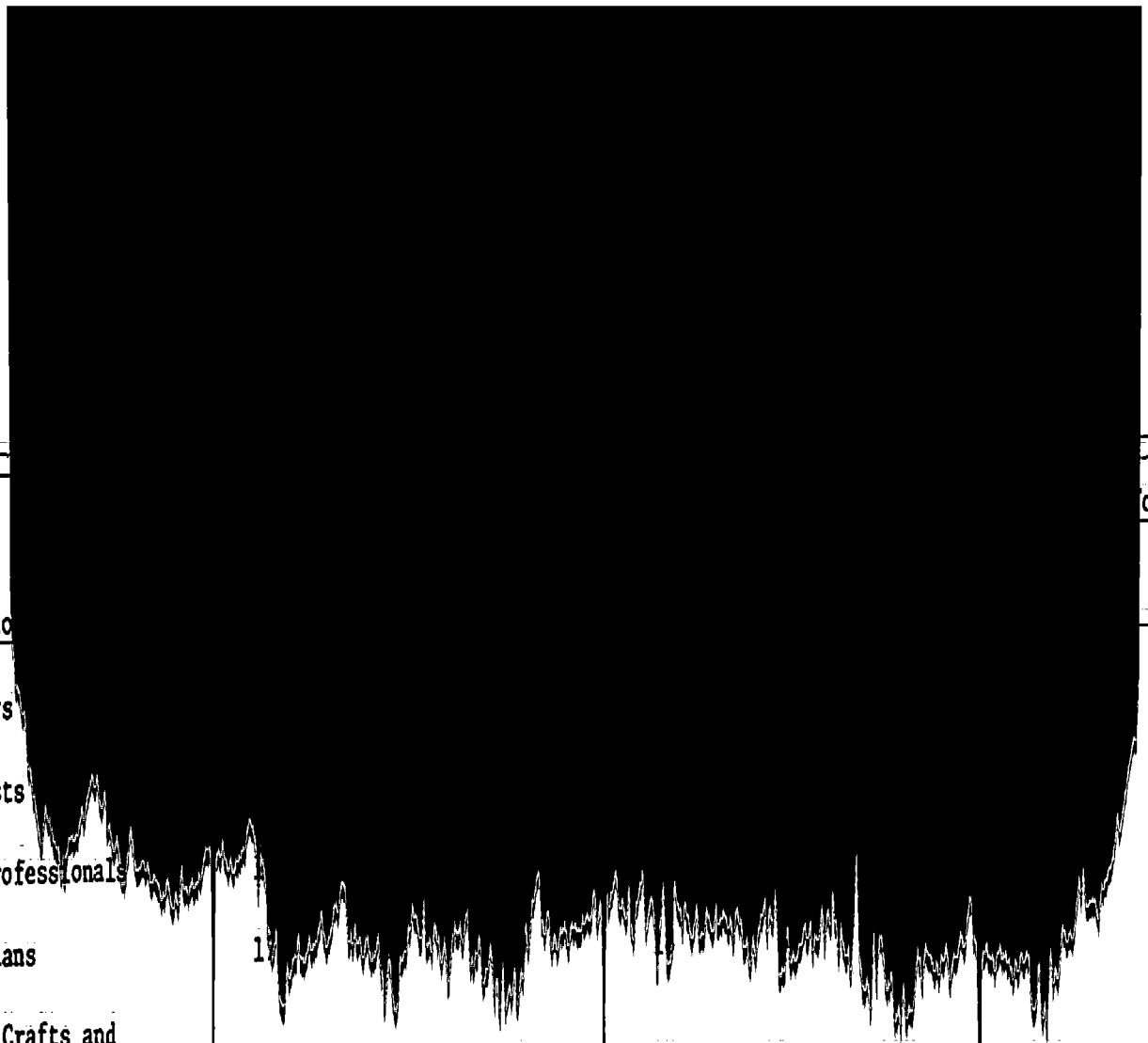
c Less than 50.

TABLE C-18. OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT IN PHOTOVOLTAIC CONVERSION, 1978. BASED ON 28 ESTABLISHMENTS

Occupational Group	Research and Development			Commercial			Total		
	Reported		Estimated	Reported		Estimated			Estimated
	N	%[a]	N[b]	N	%[a]	N[b]		%[a]	N[b]
Engineers	209	33	800	73	17	300		26	1,000
Scientists	125	20	500	16	4	100		13	500
Other Professionals	49	8	200	24	6	100		7	300
Technicians	149	23	500	19	4	100		16	600
Skilled Crafts and Operatives	63	10	200	169	40	600	232	22	800
Clerical and Unskilled Workers	40	6	100	126	30	500	166	15	600
No Occupation Given	4	1	--	0	0	--	4	0	--
Total, All Groups	639	100	2,300	427	100	1,500	1,066	100	3,800

a Total may not add to 100% due to rounding.

b Includes allocation of "No Occupation Given" category/Detail may not add to total due to rounding.

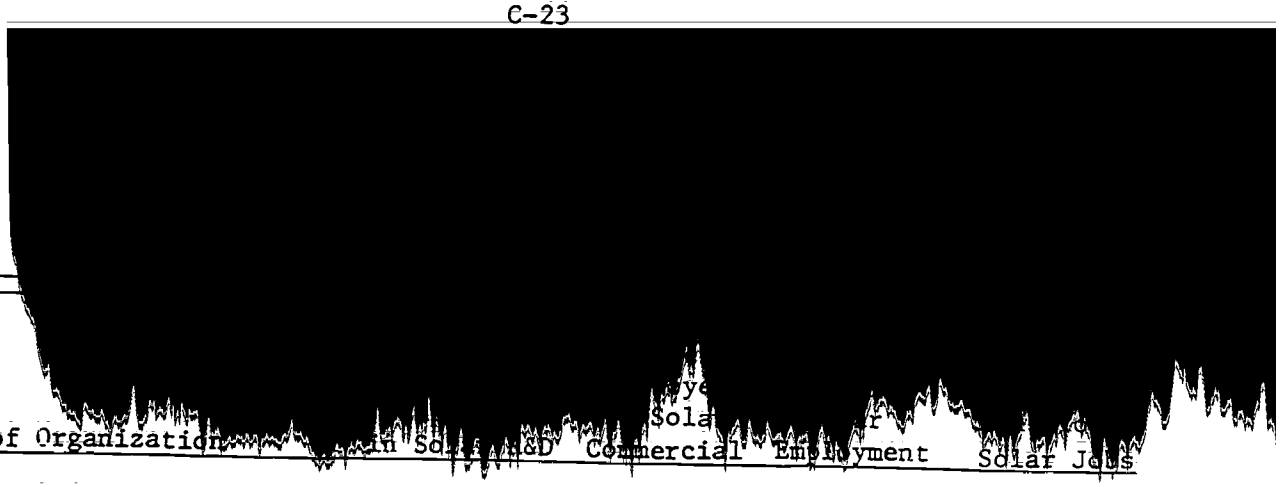


Occupatio							Total		
								%[a]	Estimated N[b]
Engineers								37	2,100
Scientists								12	700
Other Professionals								16	900
Technicians	1							13	700
Skilled Crafts and Operatives	59	5	200	63	21	200	122	8	400
Clerical and Unskilled Workers	113	9	400	67	22	200	180	12	700
No Occupation Given	30	2	--	2	1	--	32	2	--
Total, All Groups	1,226	100	4,400	301	100	1,100	1,527	100	5,500

a Total may not add to 100% due to rounding.

b Includes allocation of "No Occupation Given" category/Detail may not add to total due to rounding.

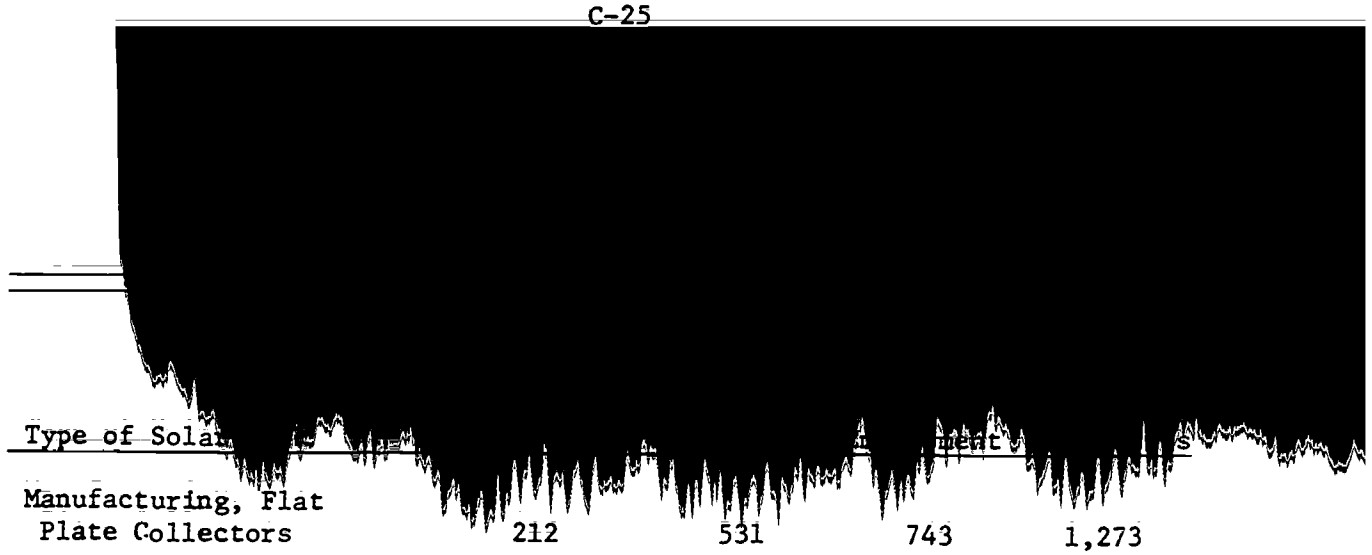
c Less than 50.



Type of Organization	Solar R&D	Solar Commercial	Employment	Solar Jobs
Private Industry	1,851	2,425	4,276	4,476
Construction Contractor	127	205	332	365
Public Utility	171	38	209	50
Federal Government	217	17	234	1
State or Local Government	142	35	177	78
Nonprofit Organization	383	36	419	152
Educational Institution	510	16	526	206
Other	7	1	8	40
Total	3,408	2,773	6,181	5,368

TABLE C-21. SOLAR EMPLOYMENT AND ADDITIONAL SOLAR JOBS BY INDUSTRY, 1978

Industry	Reported Number Employed In Solar R&D	Reported Number Employed in Solar Commercial	Reported Total Solar Employment	Reported Number of Additional Solar Jobs
Durable Goods Manufacturing	1,018	1,733	2,751	3,180
Construction	69	205	274	395
Non-Durable Goods Manufacturing	291	72	363	317
Transportation, Communication, and Public Utilities	190	49	239	62
Wholesale or Retail Trade	23	139	162	158
Educational Services	532	53	585	203
Engineering and Architectural Services	259	393	652	379
Research Services	899	65	964	596
Other Services and Public Administration	167	43	210	71
Total	3,448	2,752	6,200	5,361



Type of Solar [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Manufacturing, Flat Plate Collectors	212	531	743	1,273
Manufacturing, Other Products	913	1,142	2,055	1,978
Installation	152	359	511	635
R&D Services	1,437	93	1,530	819
Architectural and Engineering Services	339	373	712	368
Other Services	211	252	463	200
Total	3,264	2,750	6,014	5,273

TABLE C-23. PREVIOUS AND CURRENT OCCUPATIONS OF RESPONDENT EMPLOYEES, 1978

	Occupation Before Working in Solar (N=468)	Current Occupation (N=465)
Engineers	34.4	33.3
Agricultural	0.4	0.9
Architectural	0.4	0.6
Chemical	3.0	0.4
Civil	0.6	0.0
Electrical/Electronic	6.2	4.1
Mechanical	17.5	19.4
Metallurgical/Materials	0.4	0.6
Other	5.8	7.3
Scientists	10.5	9.0
Atmospheric	0.9	0.6
Biologists	1.7	0.2
Chemists	2.1	1.7
Computer Specialists	0.9	1.1
Physicists	3.8	3.7
Other	1.1	1.7
Other Professionals	24.8	42.4
Architects	3.6	4.7
College/University Teachers	4.3	3.4
Economists	0.4	0.4
Managers/Administrators	5.8	15.5
Marketing Specialists	3.8	0.0
Operations/Systems Researchers	0.9	3.7
Other	6.0	14.6
Technicians	5.1	8.0
Drafting	1.1	0.2
Electrical/Electronic	1.1	2.4
Mechanical	0.6	1.7
Other	2.4	3.7
Skilled Crafts and Operatives	5.3	6.9
Clerical and Unskilled	3.2	0.2
Student/None	16.7	0.2

Water heating	19.3
Industrial process heat	3.0
Thermal power	5.0
Ocean thermal conversion	3.9
Photovoltaic conversion	11.0
Wind conversion	3.9
Biomass conversion	1.0
Other	4.7

[redacted]

Research and development	[illegible]
Manufacturing	8.0
Marketing and distribution	13.3
Installation and maintenance	7.2
Other commercial activities	6.4
Other	15.2

TABLE C-26. PRIMARY SOLAR WORK ACTIVITIES OF RESPONDENT EMPLOYEES BY TYPE OF SOLAR ENERGY, 1978

Primary Solar Work Activity	Type of Solar Energy															
	Space Heating and Cooling		Water Heating		Industrial Process Heat		Thermal Power		Ocean Thermal Conversion		Photovoltaic Conversion		Wind Conversion		Biomass Conversion		Other	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Research and Development	77	45.0	12	17.1	8	72.7	16	88.9	12	85.7	32	80.0	9	64.3	6	85.7	9	52.9
Manufacturing	9	5.3	14	20.0	1	9.1	0	0.0	0	0.0	2	5.0	0	0.0	0	0.0	3	17.6
Marketing and Distribution	22	12.9	17	24.3	2	18.2	1	5.6	0	0.0	3	7.5	1	7.1	0	0.0	2	11.8
Installation and Maintenance	11	6.4	13	18.6	0	0.0	0	0.0	0	0.0	1	2.5	1	7.1	0	0.0	0	0.0
Other Commercial Activities	14	8.2	5	7.1	0	0.0	0	0.0	0	0.0	1	2.5	2	14.3	0	0.0	1	5.9
Other	38	22.2	9	12.9	0	0.0	1	5.6	2	14.3	1	2.5	1	7.1	1	14.3	2	11.8
Total	171	100.0	70	100.0	11	100.0	18	100.0	14	100.0	40	100.0	14	100.0	7	100.0	17	100.0

TABLE C-27. AGE DISTRIBUTION OF RESPONDENT EMPLOYEES, 1978

Age	Percent of Respondents (N=480)
20-24	8.8
25-29	19.6
30-34	15.8
35-39	16.5
40-44	11.5
45-49	8.8
50-54	10.0
55 and up	9.2

TABLE C-28. HIGHEST LEVEL OF FORMAL EDUCATION OF RESPONDENT EMPLOYEES, 1978

Highest Educational Level	Percent of Respondents (N=479)
Less than high school	0.2
High school or equivalent	4.8
Some college	10.5
Associate or technical degree	3.5
Bachelor's degree	27.6
Master's degree	26.1
Ph.D., Ed.D., or M.D.	16.7
Other	0.4

TABLE C-29. MAJOR FIELD OF STUDY OF RESPONDENT EMPLOYEES, 1978

Major Field	Percent of Respondents (N=477)
Engineering	48.2
Physical Science/ Mathematics/Biology	16.8
Other baccalaureate or professional fields	22.9
Fields of study below the baccalaureate level	12.2

TABLE C-30. HIGHEST LEVEL OF FORMAL EDUCATION OF RESPONDENT EMPLOYEES BY TYPE OF SOLAR ENERGY, 1978

Highest Level of Formal Education	Type of Solar Energy: Space Heating and Cooling N	%	Water Heating N	%	Industrial Process Heat N	%	Thermal Power N	%	Ocean Thermal Conversion N	%	Photovoltaic Conversion N	%	Wind Conversion N	%	Biomass Conversion N	%	Other N	%
High School Diploma or Less	6	3.5	8	11.4	0	0.0	0	0.0	0	0.0	1	2.5	1	7.1	0	0.0	3	17.6
Some College	16	9.4	13	18.6	0	0.0	0	0.0	0	0.0	6	15.0	0	0.0	0	0.0	2	11.8
Associate or Technical Degree	9	5.3	3	4.3	0	0.0	0	0.0	0	0.0	1	2.5	1	7.1	0	0.0	0	0.0
Bachelor's Degree	71	41.8	27	38.6	3	27.3	3	16.7	6	42.9	10	25.0	7	50.0	2	28.6	3	17.6
Master's Degree	47	27.6	15	21.4	5	45.5	8	44.4	4	28.6	7	17.5	1	7.1	1	14.3	3	17.6
Ph.D., Ed.D., M.D.	21	12.4	4	5.7	3	27.3	7	38.9	4	28.6	15	37.5	4	28.6	4	57.1	6	35.3
Total	170	100.0	70	100.0	11	100.0	18	100.0	14	100.0	40	100.0	14	100.0	7	100.0	17	100.0

TABLE C-31. HIGHEST LEVEL OF FORMAL EDUCATION OF RESPONDENT EMPLOYEES BY PHASE OF SOLAR WORK, 1978

Highest Level of Formal Education	Phase of Solar Work: Research and Development N	%	Manufacturing N	%	Marketing and Distribution N	%	Installation and Maintenance N	%	Other Commercial Activities N	%	Other N	%
High School Diploma or Less	5	2.8	5	17.2	4	8.3	3	11.5	1	4.3	1	1.9
Some College	12	6.6	10	34.5	5	10.4	5	19.2	1	4.3	4	7.4
Associate or Technical Degree	6	3.3	1	3.4	3	6.3	2	7.7	1	4.3	1	1.9
Bachelor's Degree	51	28.2	7	24.1	24	50.0	11	42.3	13	56.5	26	48.1
Master's Degree	50	27.6	6	20.7	10	20.8	5	19.2	6	26.1	14	25.9
Ph.D., Ed.D., M.D.	57	31.5	0	0.0	2	4.2	0	0.0	1	4.3	8	14.8
Total	181	100.0	29	100.0	48	100.0	26	100.0	23	100.0	54	100.0

TABLE C-32. PERCENTAGE OF HOURS SPENT IN SOLAR WORK BY RESPONDENT EMPLOYEES BY TYPE OF SOLAR ENERGY, 1978

Percent Hours Worked in Solar	Type of Solar Energy: Space Heating and Cooling N	%	Water Heating N	%	Industrial Process Heat N	%	Thermal Power N	%	Ocean Thermal Conversion N	%	Photovoltaic Conversion N	%	Wind Conversion N	%	Biomass Conversion N	%	Other N	%
Less than 50%	56	33.5	10	15.6	2	18.2	1	6.3	4	30.8	5	13.2	4	28.6	5	71.4	5	29.4
50% - 99%	38	22.8	17	26.6	4	36.4	4	25.0	3	23.1	11	28.9	5	35.7	0	0.0	4	23.5
100%	73	43.7	37	57.8	5	45.5	11	68.8	6	46.2	22	57.9	5	35.7	2	28.6	8	47.1
Total	167	100.0	64	100.0	11	100.0	16	100.0	13	100.0	38	100.0	14	100.0	7	100.0	17	100.0

TABLE C-33. PERCENTAGE OF HOURS SPENT IN SOLAR WORK BY RESPONDENT EMPLOYEES BY PHASE OF SOLAR WORK, 1978

Percent Hours Worked in Solar	Phase of Solar Work: Research and Development N	%	Manufacturing N	%	Marketing and Distribution N	%	Installation and Maintenance N	%	Other Commercial Activities N	%	Other N	%
Less than 50%	41	23.6	4	13.8	10	22.7	11	42.3	11	47.8	15	29.4
50% - 99%	51	29.3	3	10.3	15	34.1	6	23.1	3	13.0	8	15.7
100%	82	47.1	22	75.9	19	43.2	9	34.6	9	39.1	28	54.9
Total	174	100.0	29	100.0	44	100.0	26	100.0	23	100.0	51	100.0

TABLE C-34. PERCENTAGE OF HOURS SPENT IN SOLAR WORK BY RESPONDENT EMPLOYEES BY TYPE OF ORGANIZATION, 1978

	Type of Organization							
Percent Hours Worked In Solar	Private Industry N %	Construction Contractor N %	Public Utility N %	Federal Government N %	State or Local Government N %	Nonprofit Organization N %	Educational Institution	Other N %
Less than 50%	57 25.2	7 33.3	13 56.5	7 43.8	4 19.0	12 34.3	[illegible]	1 50.0
50%-99%	51 22.6	6 28.6	7 30.4	0 0.0	8 38.1	12 34.3	11 [illegible]	1 50.0
100%	118 52.2	8 38.1	3 13.0	9 56.3	9 42.9	11 31.4	16 38.1	[illegible]
Total	226 100.0	21 100.0	23 100.0	16 100.0	21 100.0	35 100.0	42 100.0	[illegible]

TABLE C-5. PERCENTAGE HOURS SPENT IN SOLAR WORK BY RESPONDENT EMPLOYEES BY INDUSTRIAL CLASSIFICATION OF ESTABLISHMENT, 1978

Percent Hours Worked in Solar	Industry																	
	Durable Goods Manufacturing		Construction		Nondurable Goods Manufacturing		Transportation, Communications and Public Utilities		Wholesale or Retail Trade		Educational Services		Engineering and Architectural Services		Research Services		Other Services and Public Administration	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Less than 50%	14	13	9	37.5	5	27.8	14	51.9	3	15.8	23	41.8	25	55.6	16	24.6	6	21.4
50%-99%	21	19.6	5	20.8	5	27.8	9	33.3	6	31.6	14	25.5	9	20.0	17	26.2	11	39.3
100%	72	67.3	10	41.7	8	44.4	4	14.8	10	52.6	18	32.7	11	24.4	32	49.2	11	39.3
Total	107	100.0	24	100.0	18	100.0	27	100.0	19	100.0	55	100.0	45	100.0	65	100.0	28	100.0

TABLE C-36. PERCENTAGE HOURS SPENT IN SOLAR WORK BY RESPONDENT EMPLOYEES BY TYPE OF SOLAR WORK OF ESTABLISHMENT, 1978

Percent Hours Worked in Solar	Type of Solar Work: Manufacturing Flat Plate Collectors N	%	Manufacturing Other Products N	%	Installation N	%	Research and Development Services N	%	Architectural and Engineering Services N	%	Other Services N	%
Less than 50%	8	17.8	13	16.9	10	30.3	40	33.3	27	52.9	19	32.2
50% - 99%	10	22.2	13	16.9	10	30.3	31	26.4	10	19.6	19	32.2
100%	27	60.0	51	66.2	13	39.4	46	40.5	14	27.5	21	35.6
Total	45	100.0	77	100.0	33	100.0	117	100.0	51	100.0	59	100.0

TABLE C-37. PERCENTAGE HOURS SPENT IN [illegible] WORK BY RESPONDENT EMPLOYEES BY ESTABLISHMENT SIZE, 1978

Percent Hours Worked in [illegible]	Total Employment								
	1-2	3-5	6-10	11-20	21-40	41-100	101-400	401-3000	Greater than 3000
	N %	N %	N %	N %	N %	N %	N %	N %	N %
Less than 50%	14 48.3	7 23.3	7 15.6	11 28.2	15 42.9	17 35.4	15 37.5	16 24.6	16 27.1
50 - 99%	4 13.[illegible]	2 40.0	9 20.0	10 25.6	11 31.4	12 25.0	12 30.0	15 23.1	12 20.3
100%	11 37.[illegible]	11 36.7	29 64.4	18 46.2	9 25.7	19 39.6	13 32.5	34 52.3	31 52.5
Total	29 100.[illegible]	30 100.0	45 100.0	39 100.0	35 100.0	48 100.0	40 100.0	65 100.0	59 100.0

TABLE C-38. SUITABILITY OF EDUCATION AND TRAINING TO SOLAR WORK ACTIVITIES AS REPORTED BY EMPLOYEES, 1978

Category	Mean Percent of Time Spent in Category (N=467)
Work requiring more education and training	18.9
Work well suited to level of education and training	61.2
Work requiring less education and training	19.9

TABLE C-39. NUMBER AND PERCENTAGE OF RESPONDENT EMPLOYEES WHO FELT THAT THEIR JOBS REQUIRED SPECIAL SKILLS OR KNOWLEDGE, AND WHO COMPLETED FORMAL SOLAR TRAINING PROGRAMS, BY PHASE OF SOLAR WORK, 1978

	Phase of Solar Work											
	Research and Development		Manufacturing		Marketing and Distribution		Installation and Maintenance		Other Commercial Activities		Other	
	N	%	N	%	N	%	N	%	N	%	N	%
Special Skills or Knowledge Required	166	92.7	22	75.9	41	85.4	23	88.5	21	91.3	49	89.1
Formal Solar Training Programs Completed	52	28.7	4	13.8	15	31.3	12	46.2	14	60.9	24	43.6

TABLE C-40. NUMBER AND PERCENTAGE OF RESPONDENT EMPLOYEES WHO FELT THAT THEIR JOBS REQUIRED SPECIAL SKILLS OR KNOWLEDGE, AND WHO COMPLETED FORMAL SOLAR TRAINING PROGRAMS, BY TYPE OF SOLAR ENERGY, 1978

	Type of Solar Energy													
	Space Heating and Cooling		Water Heating		Industrial Process Heat		Thermal Power		Ocean Thermal Conversion		Photovoltaic Conversion		Wind Conversion		Biomass Conversion		Other	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Special Skills or Knowledge Required	152	89.4	61	87.1	10	90.9	16	94.1	13	92.9	37	92.5	12	85.7	7	100.0	14	82.4
Formal Solar Training Program Completed	75	43.9	26	37.1	2	18.2	3	16.7	3	21.4	4	10.0	3	21.4	2	28.6	3	17.6

TABLE C-41. NUMBER AND PERCENTAGE OF RESPONDENT EMPLOYEES WHO FELT THAT THEIR JOBS REQUIRED SPECIAL SKILLS OR KNOWLEDGE, AND WHO COMPLETED FORMAL SOLAR TRAINING PROGRAMS, BY INDUSTRIAL CATEGORY OF ESTABLISHMENT, 1978

	Industry													
	Durable Goods Manufacturing		Construction		Nondurable Goods Manufacturing		Transportation, Communications and Public Utilities		Wholesale or Retail Trade		Educational Services		Engineering and Architectural Services		Research Services		Other Services and Public Administration	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Special Skills or Knowledge Required	96	84.2	22	88.0	17	89.5	26	92.9	16	80.0	54	91.5	43	87.8	61	93.8	28	96.6
Formal Solar Training Programs Completed	27	23.5	7	28.0	3	15.8	16	57.1	13	65.0	24	40.0	27	55.1	26	39.4	13	44.8

	Flat Plate Collectors		Other Products		Installation		Development Services		Architectural and Engineering Services		Other Services	
	N	%	N	%	N	%	N	%	N	%	N	%
Special Skills or Knowledge Required	39	78.0	71	89.9	31	88.6	115	92.7	49	89.1	56	88.9
Formal Solar Training Programs Completed	12	24.0	19	23.8	11	31.4	45	35.7	33	60.0	35	55.6

TABLE C-43. RELATIONSHIP BETWEEN EMPLOYEES WHOSE JOBS REQUIRE SPECIAL SKILLS AND KNOWLEDGE AND COMPLETION OF FORMAL SOLAR TRAINING PROGRAMS, 1978

Formal Solar Training Programs Completed	Special Skills or Knowledge Required: Yes N	Yes %	No N	No %
Yes	164	39.0	13	23.6
No	257	61.0	42	76.4
Total	421	100.0	55	100.0

$X^2 = 4.887$, df = 1, $p < .05$

TABLE C-44. SUBJECT MATTER, FREQUENCY, AND AVERAGE DURATION OF SOLAR TRAINING PROGRAMS AND COURSES AS REPORTED BY EMPLOYEES, 1978

Subject Matter	Number of Training Programs or Courses Taken	Average Duration in Hours
Solar energy, general	154	19.9
Space heating and cooling	40	29.9
Water heating	3	40.3
Industrial process heat	1	1.0
Thermal power	3	43.7
Photovoltaic conversion	7	26.3
Wind conversion	3	35.3
Biomass conversion	1	99+
Collectors	7	39.7
Solar construction	6	9.7
Solar system design	27	23.8
Solar energy materials	1	50.0
Sales	4	47.5
Management	1	*
Economics	2	25.0
Installation	2	12.0
Physics	9	30.7
Physical chemistry	1	45.0
Biochemistry	1	45.0
Radiation	5	52.0
Fluid mechanics	2	72.0
Thermodynamics/heat transfer	16	37.9
Process engineering	1	45.0
Boundary layer theory	1	45.0
Microclimatology/building climatology	3	43.0
Environmental engineering	2	34.5
Computer aided design	1	*
Thermal processes	11	23.2
Meteorological area specialization	1	60.0
Atmospheric sciences	2	69.5
Mathematics	1	99+
Microcomputer simulation	1	*
Dynamics of systems (controls)	1	48.0
Energy management	3	3.0
Solar distributor	1	20.0
Energy analysis	1	16.0
Solar energy conversion	1	80.0
Power plant design	2	99+
Other	11	31.8
Unknown subject matter	16	6.7

* No hours given

APPENDIX D

METHODOLOGY USED TO FORMULATE MANPOWER PROJECTIONS

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METHODOLOGY USED TO FORMULATE MANPOWER PROJECTIONS

The solar energy manpower projections were based in part on data provided by both employer and employee surveys. Two separate methods were used for forecasting R&D and commercial solar energy manpower needs. It is in the development of the employment coefficients that the two forecasting methods differed. For R&D employment coefficients, R&D expenditures were defined as a measure of R&D output, and R&D funding was assumed to be equivalent to expenditures. The two words will therefore be used interchangeably in the following text. The R&D employment coefficients thus represent labor-hours* per dollar of R&D funding. The commercial coefficients were defined in terms of labor-hours per unit of installed solar energy equipment. Only the solar space heating and cooling, water heating, and industrial process heat (IPH) techniques were assumed to produce significant commercial output since the MITRE forecasts (see below) projected a significant number of installations by 1985 for only these techniques. The methods for computing the R&D and commercial employment coefficients discussed below treat each type of solar energy separately.

R&D Employment Coefficients

This section discusses the method used to derive the R&D coefficients and presents the numerical results. Two assumptions about R&D labor productivity are implicit in the method used to derive the labor coefficients:

- There is no productivity differential in R&D between large and small organizations.
- R&D employee productivity stays constant over time.

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* The employment (manpower) coefficients utilize labor-hours rather than number of employees in order to adjust for part-time employees. The employment of part-time people is reported in labor-hours per year. These labor-hours are used to create the coefficients. To convert the number of labor-hours required to produce a given amount of output into full-time equivalent employees, the number of labor-hours is divided by the number of labor-hours worked in a year by a full-time employed person. This conversion procedure and its underlying assumptions will be elaborated below.

The procedure for deriving the coefficients is as follows:

First, a method was developed to determine total R&D expenditure, since the total of R&D funding was not obtainable from the survey questionnaire because of industry disclosure problems. Question 10 of the employer survey questionnaire provided the percentage of funding received from each source of funding (Federal funding of R&D, other R&D funding, and commercial activity funding, and other funding) for each type of solar energy. The "other funding" category was eliminated and the percentages normalized to sum to 100 percent for each respondent. A weighted sum over all respondents of solar energy funding percentages by source was then computed. The appropriate weights for this summation are the ratios of individual respondents' total receipts of funds from each source to the total funding from that source over all respondents. Since these dollar receipts were unknown, solar energy employment was used as a proxy for solar energy funding. (This implies the assumption of no productivity differential between large and small organizations.)

The summation equations are:

$$\%F_i = \Sigma_j \%F_{ij} * (E_{ij}/\Sigma_j E_{ij})$$

$$\%O_i = \Sigma_j \%O_{ij} * (E_{ij}/\Sigma_j Eij)$$

$$\%C_i = \Sigma_j \%C_{ij} * (E_{ij}/\Sigma_j E_{ij})$$

and the resulting aggregate funding equation is

$$\%F_i + \%O_i + \%C_i = 100\%$$

where
- i = type of solar energy
- j = respondent
- %F = percent of solar activity funds coming from the Federal government for R&D purposes
- %O = percent of solar activity funds coming from all other sources for R&D purposes
- %C = percent of solar activity funds going to commercial activities
- E = solar energy employment.

See Table D-1 for these percentages.

The proportion $\%F_i$ represented of the total $\%F_i + \%O_i$ (call this proportion P_i -- see Table D-2) was applied to the dollar value of Federal solar energy funding obtained from the Federal government to estimate a total dollar funding of solar energy R&D for 1978:

$$T_i = F_i/P_i$$

where

T_i = total 1978 R&D dollar funding
F_i = Federal R&D dollar funding
P_i = the proportion the Federal R&D funding is of total R&D funding.

These results are presented in Table D-3.

Next, the total number of R&D employment labor-hours for 1978 were calculated. The employee survey provided estimates of the average employee labor-hours per week spent on solar energy R&D by primary type of solar energy (Table 25). These were averaged and multiplied by 50 to give the labor-hours per year (for 1978) for an individual employee. The labor-hours per year was multiplied by the number of employees and the result divided by the 1978 solar energy R&D funding to create the coefficients showing the number of employment labor-hours per dollar of R&D funding:

$$TLHR_i = (ALHR_i * 50 * NER_i)/RD_i$$

where

i = type of solar energy
$TLHR_i$ = annual R&D employment labor-hours per dollar of R&D funds
$ALHR_i$ = average employee labor-hours per week spent on solar energy R&D
NER_i = number of employees in solar R&D
RD_i = total annual solar R&D funds.

The coefficients are shown in Table D-4. These coefficients, though computed using the 1978 survey data, were assumed to remain constant over time (R&D productivity does not change over time).

TABLE D-1. SOLAR ENERGY EXPENDITURE PERCENTAGES BY TYPE OF ACTIVITY AND SOURCE OF FUNDS, 1978

	%F	%O	%C
	R&D Expenditures Federally Financed	R&D Expenditures Non-Federally Financed	Solar Commercial Expenditures
Space Heating and Cooling, and Water Heating	37.7	16.7	45.6
Agriculture and IPH	47.4	13.1	39.4
Thermal Power	68.7	15.7	15.6
Ocean Thermal	86.9	9.6	3.5
Photovoltaics	60.5	12.6	26.9
Wind	64.2	23.1	12.6
Biomass	67.5	17.8	14.7

TABLE D-2. PERCENTAGES OF SOLAR R&D FUNDING BY SOURCE, 1978

	P_i Federal % of R&D Funding	$100-P_i$ Non-Federal % of R&D Funding
Space Heating and Cooling and Water Heating	69	31
Agriculture and IPH	78	22
Ocean Thermal	81	19
Photovoltaics	83	17
Wind	74	26
Biomass	79	21

TABLE D-3. 1978 SOLAR R&D FUNDING

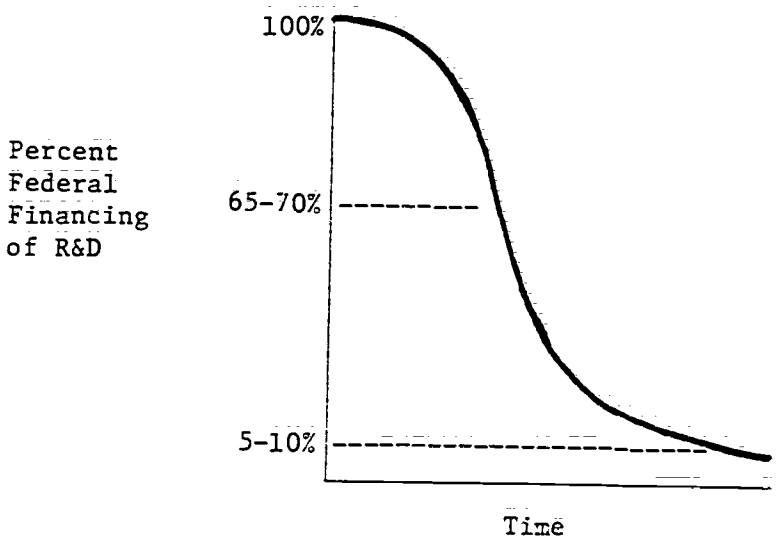
	Federal 1978 Solar R&D Funding (Thousand 1978 $)	1978 Federal Funding as % of Solar R&D Total	Total 1978 Solar R&D Funding (Thousand 1978 $)
Space Heating and Cooling and Water Heating	99,365	69	144,007
Agriculture and IPH	10,632	78	13,631
Photovoltaics	78,204	83	94,222
Other:	210,949		261,213
Thermal Power	106,418	81	131,380
Wind	37,517	74	50,699
Ocean Thermal	36,802	90	40,891
Biomass	30,212	79	38,243
Total	399,150		513,073

TABLE D-4. R&D EMPLOYMENT COEFFICIENTS

	Average Weekly Solar R&D Hours Per Employee, 1978	Annual Solar R&D Hours Per Employee, 1978	Number of Employees for 1978*	Total 1978 Solar R&D Hours (Thousands)	Total 1978 Solar R&D Funding (Thousand 1978 $)	Annual Solar R&D Labor Hrs./$ of R&D Funding
Space Heating and Cooling and Water Heating	29.2	1460	6,800	9,928	144,007	.06894
Agriculture and IPH	26.6	1330	200	266	13,631	.01951
Photovoltaics	32.3	1615	2,700	4,360.5	9,422	.04628
Other:	26.2	1310	2,800	3,668	261,213	.01404
Thermal Power	35.1	1755	600	1,053	131,380	.00801
Wind	21.2	1060	1,000	1,060	50,699	.02091
Ocean	22.4	1120	400	448	40,891	.01096
Biomass	19.2	960	800	768	38,243	.02008
Total			12,500	18,222.5	513,073	

* Includes allocation of solar employees where the primary type of solar energy was "Missing" or "Other".

In order to determine future labor needs in solar R&D, total R&D financing had to be forecasted. One way of doing this is to forecast the federal component, and determine the trend for the proportion of R&D funding financed by the Federal government. Federal involvement in R&D activities for a new industry follows a distinct pattern which can be related to the commercial maturity of the industry. The pattern formed by the proportion of R&D funding which is federally supported traces a descending S-shaped (ogive) curve, with the point of inflection occurring at about 65-70% federal involvement in R&D financing:



Above the 65-70% level, the federal government is heavily involved in the financing of R&D activities, in large part because these activities cannot yet justify themselves economically. Federal involvement slowly drops off as the activity gradually enters the commercialization stage and increases economic inducements within the private sector. When the activity reaches the stage of economic feasibility, usually after federal involvement in financing has reached the 65-70% level, federal support drops off dramatically. This judgmental conclusion is based on observations of trends in commercialized forms of solar energy.

Battelle has forecasted that Federal solar R&D funding will reach close to $1 billion (about $950 million) in 1979 dollars by 1983 (Figure 2, and Table D-5). In the 1978 constant dollars used in this study, this is approximately $880 million. These forecasts were based on Department of Energy historical data on total Federal expenditures for solar R&D by type of solar energy for 1975-1979 and preliminary projections for 1980. These past, current, and projected Federal R&D expenditures were deflated to constant dollars using the R&D deflator series developed at Battelle for its annual R&D expenditure forecasts.* This series has been rebased so that the deflator for 1978 equals 100. The forecasting method was a combination of graphic and judgemental methods. Forecasts of funding for some of the types were purely judgemental. Others were graphic extrapolations of past data (see Figure 2).

The data on Federal funding of solar energy R&D by type of solar energy were supplied by DOE and included funding by other Federal agencies. Funding data reported by the National Science Foundation (NSF)** were only for DOE, and did not break solar funding down by type of solar energy. The NSF solar totals for 1977, 1978 and 1979 are lower than those shown in Table D-5, but do not include solar funding by other agencies. Further, the NSF figures for 1978 and 1979 were only estimated levels. The recommended funding was raised by Congress, and final action was still pending at the end of 1978 when the NSF report was prepared. The 1979 DOE solar obligations were considerably higher than estimated in the NSF report. Recent data provided by NSF*** indicate that the 1980 DOE solar budget is about 652 million dollars, which is within 2 percent of the 640 million dollars used in Table D-5.

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* These deflators, developed by Dr. W. Halder Fisher, are published as Table 4 in Fisher, Dr. W. Halder, Probable Levels of R&D Expenditures in 1979: Forecast and Analysis (Columbus: Battelle Columbus Laboratories, December 1978), p. 14.

** National Science Foundation. An Analysis of Federal R&D Funding by Function. Fiscal Years 1969-1979. NSF 78-320. National Science Foundation, Washington, D.C., 1978, p. 24.

***National Science Foundation. Science Resources Studies Highlights. NSF 79-319. National Science Foundation, Washington, D.C. November 16, 1979, p. 3.

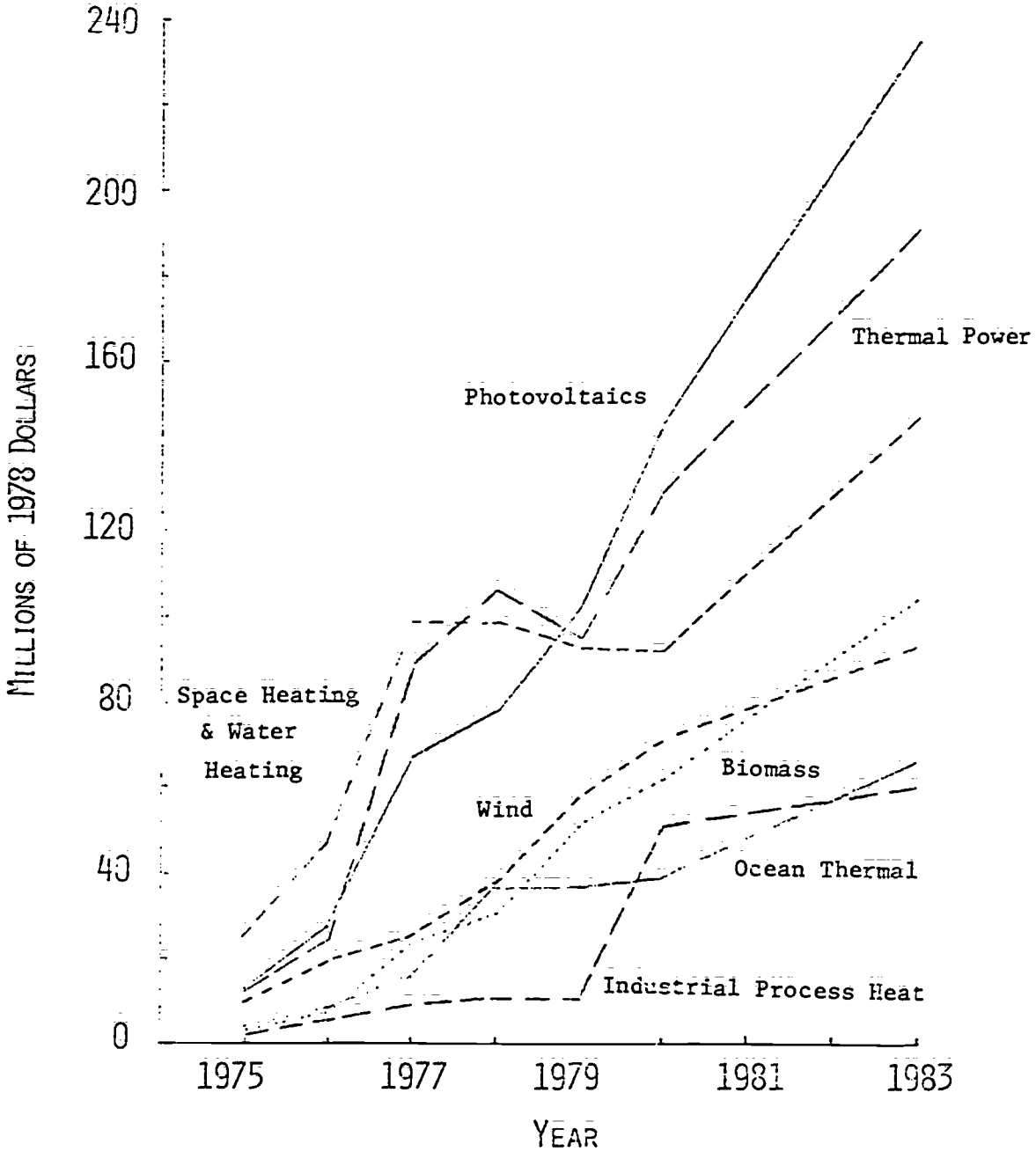

FIGURE 2. FORECAST OF FEDERAL SOLAR R&D FUNDING BY TYPE OF SOLAR ENERGY. BASED ON 1979 DATA

TABLE D-5. FEDERAL FUNDING OF SOLAR ENERGY R&D
BY YEAR AND TYPE OF SOLAR ENERGY

	(Oct.-Sept.) 1975	(Oct.-Sept.) 1976	1977	1978	1979	1980[a]	Forecast 1983
			(Thousands Current $)				
Space and Water Heating and Cooling	20,176	40,825	91,414	99,365	101,018	100,000[b]	
Agriculture and IPH	1,588	4,637	8,207	10,632	11,601	55,000	
Solar Elec.: Thermal Power	10,315	21,509	82,169	106,418	102,763	141,000	
Photovoltaics	11,196	23,900	62,016	78,204	121,960	158,000	
Wind	7,312	15,875	22,750	37,517	62,515	77,000	
Ocean Thermal	3,055	7,174	14,751	36,802	39,216	42,000	
Biomass	2,003	5,938	21,793	30,212	55,509	67,000	
Total				399,150	494,582	640,000	953,000
			(Thousands 1978 $)				
Space and Water Heating and Cooling	24,878	47,251	99,072	99,365	93,631	92,687	120,000
Agriculture and IPH	1,958	5,367	8,895	10,632	10,753	50,978	65,000
Solar Elec.: Thermal Power	12,719	24,895	89,053	106,418	95,248	130,689	192,000
Photovoltaics	13,805	27,662	67,211	78,204	113,041	146,445	236,000
Wind	9,016	18,374	24,656	37,517	57,943	71,369	100,000
Ocean Thermal	3,767	8,303	15,987	36,802	36,348	38,929	66,000
Biomass	2,470	6,873	23,619	30,212	51,450	62,100	104,000
Total	68,613	138,725	328,493	399,150	458,414	593,197	883,000

a 1980 forecasted DOE budget only, in 1979 dollars.

b Cut from original funding level request (including support services) of $153 million.

Battelle also projected the trend of federal solar R&D support as a proportion of total solar R&D support, reproduced in Table D-6.

The last year of 100% federal R&D support for each solar energy type was estimated to be as follows:

Space Heating & Cooling and Water Heating	1970
Agriculture and IPH	1973
Thermal Power	1970
Ocean Thermal	1973
Photovoltaics	1970
Wind	1970 (90%)
Biomass	1973 (90%).

The 1978 percentages of federal support are reproduced in Table D-2 referenced above. Both space heating and cooling and water heating were assumed to have reached the inflection point on the above S-shaped curve by 1978 (the inflection point represents 65-70% federal support). Agriculture and IPH will reach this point by 1980; thermal power, by 1983. All other solar types will still be above this point by 1983. The S-shaped curve was fit to the above data for each solar type, and the 1981 and 1983 federal funding percentages extrapolated along it.

These forecasts of federal solar R&D funding, plus the projections of the federal support proportion of the total solar R&D funding were used to determine the total amount of future solar R&D funding. The R&D employment coefficients (which remain constant over time since R&D productivity is assumed not to change) were applied to the projected total R&D funding levels to obtain the forecasts of solar energy R&D labor needs in terms of full-time equivalent employees (assuming a work-year of 2000 labor-hours). Table D-7 shows these labor projections. Finally, these employment projections were broken down by occupational category, using the occupational distributions of R&D employment from Table 17. These results are reported in Table D-8.

TABLE D-6. PROJECTED SOLAR R&D FUNDING

	Federal Funding (Millions 1978 $)	Percent Federal Funding	Total Funding (Millions 1978 $)
		1981	
Space Heating and Cooling and Water Heating	102	58	176
Agriculture and IPH	56	64	88
Photovoltaics	176	75	235
Other:	356		497
Thermal Power	151	72	210
Wind	81	66	123
Ocean Thermal	48	83	58
Biomass	76	72	106
Total	690		996
		1983	
Space Heating and Cooling and Water Heating	120	51	240
Agriculture and IPH	65	55	118
Photovoltaics	236	69	342
Other:	462		699
Thermal Power	192	65	295
Wind	100	61	164
Ocean Thermal	66	78	85
Biomass	104	67	155
Total	883		1399

TABLE D-7. PROJECTED SOLAR R&D EMPLOYMENT REQUIREMENTS

	Annual Solar R&D Labor Hrs./Dollar of R&D Funding	Projected Solar R&D Funding (Millions 1978 $)	Projected Solar R&D Labor Hrs. (Thous. Hours)	Projected FTE Employees (Thousands)
		1981		
Space Heating and Cooling and Water Heating	.06894	176	12,133	6.1
Agriculture and IPH	.01951	88	1,717	.9
Photovoltaics	.04628	235	10,876	5.4
Other	.01404	497	6,978	3.5
Total		996	31,704	15.9
		1983		
Space Heating and Cooling and Water Heating	.06894	240	16,546	8.3
Agriculture and IPH	.01951	118	2,302	1.2
Photovoltaics	.04628	342	15,828	7.9
Other	.01404	699	9,814	4.9
Total		1,399	44,490	22.3

TABLE D-8. OCCUPATIONAL DISTRIBUTION FOR PROJECTED SOLAR R&D EMPLOYMENT (THOUSANDS OF FULL-TIME EQUIVALENT EMPLOYEES)

	Space Heating and Cooling Plus Water Heating	Agriculture and Industrial Process Heat	Photovoltaics	Other
		1981		
Total Projected FTE Employment	6.1	.9	5.4	3.5
Engineers	2.5	.4	2.2	1.4
Scientists	.8	.1	.7	.5
Other Professionals	.9	.1	.8	.5
Technicians	.9	.1	.8	.5
Skilled Crafts and Operatives	.4	.1	.4	.2
Clerical and Unskilled Workers	.6	.1	.5	.3
		1983		
Total Projected FTE Employment	8.3	1.2	7.9	4.9
Engineers	3.4	.4	3.2	2.0
Scientists	1.1	.2	1.1	.7
Other Professionals	1.2	.2	1.1	.7
Technicians	1.2	.2	1.1	.7
Skilled Crafts and Operatives	.6	.1	.6	.3
Clerical and Unskilled Workers	.8	.1	.7	.5

Commercial Employment Coefficients

The commercial analysis involved only the actual solar system - collector or concentrator - itself, not any of the ancillary components.* The respondents varied as to whether they manufactured in-house some or all of the basic components of the actual system. The problems this variation incurred will be touched on below in the discussion of the results. Only the direct labor involved in production and installation of the system was considered. For swimming pools, the average panel size was 40 square feet; for space heating and cooling and domestic hot water, the size range was 15-20 square feet. A typical concentrator module ranged from 480-660 square feet.

The employer and employee surveys did not provide all the information necessary to compute the commercial manpower coefficients for space heating and cooling, water heating, and industrial process heat (IPH), because businesses consider the needed sales data to be proprietary information. Therefore, as an alternative procedure, Battelle surveyed a selected small sample of companies (3 for water heating, including swimming pool heaters, 3 for space heating and cooling, and 3 for IPH) involved in all aspects of commercial solar activity to determine present levels of and future changes in employment labor-hours requirements per unit of output. The survey respondents requested that their company names not be disclosed in order to protect proprietary production information. In fact, other companies refused to respond, citing their fear of disclosure of such information, which could quickly lead to a loss of competitive position in an infant industry such as the solar energy industry.

Battelle also solicited information on employment requirements and future productivity changes from its own solar energy engineers. In addition, installation labor requirements for space heating and cooling and domestic hot water heating were available from Building Construction Cost Data, 1978, Robert Snow Means Co., Duxbury, 1978, pp. xi, xii, 234, and 345. Estimates of manufacturing and installation labor requirements for new

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* The one exception is for domestic hot water heating systems, the installation of which includes installation of a storage tank.

installations were also obtained from reports of the Solar Energy Research Institute (SERI).* The information from industry and Battelle sources was used to determine the employment coefficients representing labor-hours per square foot of collector surface for each commercial solar industry, and projections of how these coefficients will change in five years.

The labor-hours/square foot requirements specified by the individual respondents were averaged together. Table D-9 gives the 1978 labor coefficients for collectors and concentrators. These requirements were for low and medium temperature flat plate collectors and parabolic trough concentrators. Information on non-tracking, evacuated tube concentrators was not provided, since they are so new that no respondents could be found who were willing to disclose any production information. The proportions of various types of collectors and concentrators used for swimming pool heating, domestic hot water heating, and space heating and cooling were obtained from Solar Collector Manufacturing Activity, July 1977 Through June 1978, U.S. Department of Energy, Energy Information Administration, February 1979, p. 12, Table 5: 1978 January through June. Evacuated tube concentrators are included in this table and were considered to have the same labor requirements as parabolic trough concentrators. The proportions of collectors and concentrators used for industrial process heat came from Battelle solar engineers, since this category was not separately identified in the DOE table.

The proportions used were:

	Low Temperature Collectors	Medium Temperature Collectors	Concentrators
Swimming Pool	94%	6%	--
Domestic Hot Water	6%	91%	3%
Space Heating and Cooling	5%	81%	15%
IPH	--	15%	85%

*Mason, Bert. Labor, Manpower and Training Requirements. SERI/PR-53-073, Solar Energy Research Institute, Golden, Colorado, September 1978. Tables 1 and 3.

Mason, B., Ferris, G., and Burns, B. Solar Energy Commercialization and the Labor Market. SERI/TP-53-123, Solar Energy Research Institute, Golden, Colorado, December 1978. Table 2.

TABLE D-9: 1978 COMMERCIAL DIRECT LABOR REQUIREMENTS BY TYPE OF COLLECTOR/CONCENTRATOR (LABOR-HOURS/ SQUARE FOOT)

	Low Temperature Collector	Medium Temperature Collector	Concentrator
	.025	.15	.33
	.055	.65	.22
	.080	.80	.55

collecto clude both nd liquid
requireme re practic dentical,
y 1983 Ba e estimate the use
PH will have nished to 5%.

Domestic hot water heating and space heating and cooling labor requirements were averaged together, since sales projections for these two solar energy end uses were not available separately. The weights were based on sales market share projections* obtained from the Solar Energy Industries Association (SEIA), The Solar Future-1978, Tables 3 and 5. These are:

	1978	1981	1983
Domestic Hot Water	24.6%	27.6%	35.1%
Space Heating & Cooling	75.4%	72.4%	64.9%

Finally, productivity changes were anticipated by both our respondents and Battelle engineers in production, though not in installation. These changes are:

Low temperature collectors: no change

Medium temperature collectors: 30% reduction in labor

Concentrators: 50% reduction in labor.

Table D-10 gives current and projected labor coefficients by solar end-use as obtained using the above proportions of collection and concentrator applications. 1981 values were obtained through linear interpolation. As stated above, installation for domestic hot water heating includes installation of a storage tank. Installation of a concentrator includes site work as well as the actual equipment installation. Again, these coefficients represent direct labor only for production and installation. Table D-11 displays the Battelle current labor coefficients along with their SERI report counterparts for new systems from SERI Tables 1 and 3. Problems with these coefficients will be discussed in the next section.

Projections of commercial solar equipment sales for domestic hot water heating plus space heating and cooling, and industrial process heat

* The sales associated here with space heating and cooling actually involve systems which include domestic hot water heating. But these were considered appropriate as indications of the market share of space heating and cooling.

		Swimming Pool Heating	
Production	.03	.03	.03
Installation	.09	.09	.09
Total	.12	.12	.12
		Domestic Hot Water	
Production	.15	.13	.11
Installation	.82	.82	.82
Total	.97	.95	.93
		Space Heating and Cooling	
Production	.17	.14	.12
Installation	.60	.60	.60
Total	.77	.74	.72
		Domestic Hot Water and Space Heating and Cooling*	
Production	.15	.13	.11
Installation	.77	.77	.77
Total	.92	.90	.88
		Industrial Process Heat	
Production	.30	.22	.18
Installation	.28	.28	.28
Total	.58	.50	.46

* These coefficients are an average of domestic hot water and space heating and cooling weighted by market shares (see text).

	Battelle	SERI	Mitre	Public Policy Center	Navarro College**
			Domestic Hot Water		
Production	.15	.27	.28	.25	
Installation	.82	.79	.60	.80	.80
			Domestic Hot Water and Space Heating		
Production	.15*	.27	.48	.15	
Installation	.77*	.89	1.07	.32	.42

* Battelle's coefficients represent Domestic Hot Water, Space Heating and Cooling.

** Average of four data collection methods.

could be found. These forecasts were converted from quads to square feet of collector surface, using Battelle determined average B.T.U. conversion factors of 206,000 Btu/Ft^2/Yr. for flat plate collectors and 275,000 Btu/Ft^2/Yr. for parabolic trough concentrators. These sales forecasts were then applied to the Battelle manpower coefficients projections to obtain the forecasts of solar commercial full-time equivalent employee requirements [illegible] hours per work-year). Table D-12 presents these results.

These employment forecasts represent direct labor requirements only -- the Skilled Crafts and Operatives category in our occupational distribution. To obtain total projected labor requirements, these direct labor requirements were first scaled up to a total requirements figure based on the percentage of total employment represented by the Skilled Crafts and Operatives category in the occupational distribution for solar commercial employment (Table 17). Then this total was broken down into its component occupational categories, based on the assumption that the survey-derived commercial occupational distribution would remain constant for the next five years. These commercial solar labor requirements are presented in Tables D-13 and D-14.

Discussion of Projections

Table D-15 presents the projected changes in solar R&D employment for different types of solar energy. The table combines and compares data presented in Tables D-4 and D-7. Full time equivalent R&D employment is projected to increase from 9,111 in 1978 to 15,852 in 1981, a gain of 74 percent. Full-time equivalent R&D employment is further projected to increase to 22,240 in 1983, a gain of 144 percent over 1978.

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* Bennington, G., et al., Solar Energy, A Comparative Analysis to the Year 2000. Mitre Technical Report #MTR-7579, March 1978, under contract with ERDA, Division of Solar Energy.

Scientists

Skilled crafts and operatives

Total Projected Job* Employment

*Detail may not add to total due to rounding.

Lastly, these studies do not, and in fact can not, anticipate both changing production techniques and the resulting changes in occupational requirements over-time. Only a thorough engineering study can overcome the above deficiencies in the estimation techniques that have been used.

*U.S. GOVERNMENT PRINTING OFFICE : 1980 0-620-309/45