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SOLAR ENERGY COMMERCIALIZATION AND THE LABOR MARKET

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NOTICE

SOLAR ENERGY COMMERCIALIZATION AND THE LABOR MARKET

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ABSTRACT

The success of a new technology does not depend only on its technical and economic feasibility. Evidence from the diffusion of non-solar technologies suggests that unless the product can be accepted and integrated into existing institutional processes and practices and can meet specific user and technology delivery system requirements, acceptance and diffusion of the technology will be slow.

This paper discusses the potential impacts of solar energy commercialization on labor demand, and conversely, the potential impacts of the labor supply system on solar energy commercialization. Various participants in manpower training programs are examined, and alternative implementation channels to meet the labor needs of an emerging technology are discussed.

INTRODUCTION

Labor market implications of solar energy commercialization are potentially important in two respects. First, significant market penetration of solar energy technologies may create expanded employment opportunities with different skill requirements. Second, labor supply (in terms of quantity, skills, and geographic location) may affect the extent of adoption, consumer acceptance, and competitiveness of solar technologies in energy markets.

The purpose of this paper is to discuss the potential impacts of solar energy on labor demand, and conversely, the potential impact of the labor supply system on solar energy commercialization. Estimates of direct and total labor requirements to design, manufacture, install, and maintain selected solar systems are provided. Current solar-related training efforts are reviewed, and research needs and policy issues are identified and discussed.

RELATIVE LABOR INTENSITY OF SOLAR ENERGY

It is often inferred that solar energy is considerably more labor intensive than conventional energy sources and that expansion of the solar industry will create many jobs. Results of a recent study by the Domestic Policy Review of Solar Energy [1] provide estimates of the direct and indirect labor requirements for conventional and solar energy technologies.[a] These data are presented in Table 1; an explanation of the derivation of these

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data is presented in the next section.

To provide some basis for comparing the various energy technologies, labor requirements are based on the number of person-hours per million Btu's (MMBtu) of oil displaced. The data in Table 1 indicate that the various solar energy technologies, with the exception of biomass, are 1.5 to 5 times more labor intensive (per MMBtu) than conventional energy sources. If these estimates are reasonably accurate, solar energy technologies will demand considerably more labor input than conventional energy sources such as coal, petroleum, natural gas, and nuclear energy.

It should be emphasized that the data in Table 1 represent only the labor inputs per unit of energy output; no consideration is given to capital requirements for each energy source. It may be true that solar energy technologies also require considerably more capital per MMBtu than conventional sources. In proportion to total cost, solar energy may therefore require more, less, or the same amount of labor per dollar of total cost as coal, oil, gas, or nuclear energy. But the statistics in Table 1 do suggest that solar energy requires more labor per unit of output than conventional sources.

DIRECT LABOR REQUIREMENTS FOR LIQUID FLAT-PLATE COLLECTOR SYSTEMS (RHW and SH)

Most of the existing research on direct labor requirements focuses on a single solar energy technology--liquid flat-plate collectors for residential hot water (RHW) and space heating (SH) applications. Results from four separate studies on direct labor requirements for RHW systems and combined RHW/SH systems are summarized in Table 2. To allow comparison among the estimates, results are reported on the basis of person-hours per square foot of collector area (ph/ft^2).

As indicated by data in Table 2, there is significant variance among the labor estimates of the four studies. Part of the discrepancies can be explained by different methodologies and definitions. None of the studies includes all of the steps necessary to produce and deliver solar systems. Perhaps the most important reason for the differences is the nascent state of the solar industry. At this stage, procedures for estimating solar labor needs are part observation and part hypothesis. More precise and consistent estimates will be obtainable only when substantial market experience is achieved.

An indication of total direct labor requirements for typical residential applications can be provided by multiplying estimates of person-hours per square foot of collector area (from Table 2) by collector requirements for representative systems. A recent study [6] has estimated that "typical" collector areas are 84 ft^2 for RHW and 350 ft^2 for RHW/SH systems. A RHW system would require a total of approximately 170 person-hours, while labor input (to design, manufacture, and install) a combined RHW/SH system would require approximately 550 person-hours.

To provide some basis of comparison between the DPR labor estimates for residential water and space heating (Table 1) and those summarized in Table 2, the latter data must be converted to person-hours per MMBtu. Details of this conversion are provided in footnote b at the end of the text.[b] Results from the four studies summarized in Table 2 estimate that solar energy will require approximately 0.82 person-hour per MMBtu of oil displaced for RHW and 1.38 person-hours per MMBtu of oil displaced for RHW/SH. These estimates are approximately the same as those of the DPR (0.933 ph/MMBtu for RHW and 1.433 ph/MMBtu for SH).

CHANGES IN LABOR/OUTPUT RATIOS FOR SELECT SOLAR ENERGY TECHNOLOGIES

To predict future labor requirements of solar energy, it is necessary to identify probable trends in economies of scale and "learning by doing" in various segments of the industry. Labor requirements have not generally been analyzed on a longitudinal basis; available research is therefore not able to ascertain if scale economies, learning effects, or technological developments have altered labor requirements or are likely to do so in the future. This section presents some preliminary data on trends in labor/output ratios from a recent ORAU/SERI study [5]. Technologies surveyed include photovoltaics, small-scale wind energy conversion systems, and residential space and hot water heating.

Photovoltaics

Two photovoltaic manufacturing firms, which account for about 35% to 40% of photovoltaic production in the United States, were interviewed to determine their labor requirements and labor/output ratios. The only specific information the firms would release were the current employment levels and the approximate number of staff employed in specific occupational areas. Interview data indicate that approximately 220 to 280 person-hours of skilled and unskilled labor are required per peak kilowatt of production.

Some qualitative data on trends in labor/output ratios over the last few years were provided. Both firms indicated their output and sales have doubled in each of the last three years and that their employment had also doubled in each year; labor/output ratios have remained relatively constant over the last three years.

However, both firms felt their labor/output ratios would eventually decrease as their output continues to expand and some economies of scale could be attained. One firm indicated that scale economies will occur when output grows to a level sufficient to permit the economical use of automated assembly line techniques.

Wind Energy Conversion Systems

Two wind energy system firms were interviewed. These two firms are the largest manufacturers and installers of small-scale wind systems (3 kw or less) in the United States. One firm has been involved primarily in design, sales, fabrication, and installation of foreign-manufactured components, while the other designs, manufactures, and installs complete systems. These interviews revealed that present labor/output ratios were considered high and that they would be reduced substantially by higher output volumes. One firm indicated that it was already experiencing decreasing labor/output ratios; between 1975 and 1976, person-years per unit of output (2-3 kw machines) decreased from 0.80 to 0.44. The second firm was unable to provide detailed estimates of historical labor/output ratios but predicted that unit costs for manufacture could be reduced by two-thirds at mass production levels. At present, this firm requires approximately 100 person-hours to design, manufacture, and fabricate a 1 kw to 2 kw system. Installation requires 14 to 16 person-days.

Residential Space and Hot Water Systems

Five solar hot water and space heating firms were interviewed and two of the interviews yielded data on labor/output trends (Table 3). These data indicate that as total output increased, the labor/output ratios were reduced substantially. In addition to the quantitative evidence on reductions in labor/output ratios, qualitative statements were solicited from the solar collector systems firms. In general, most solar firm representatives believe that labor savings will occur as business volume increases. Most estimated that both economy of scale and learning-by-doing will occur with experience and increased output.

Preliminary evidence suggests that significant reductions in labor/output ratios have been achieved for some solar energy technologies. The present sample is extremely small and no statistical validity can be assigned. However, the general consensus of industry representatives is that labor requirements per unit of output will decrease as the industry expands. It is not possible at this stage to calculate future labor/output ratios, but these tentative findings should be kept in mind when examining solar energy employment projections.

SKILL REQUIREMENTS FOR SELECTED SOLAR ENERGY TECHNOLOGIES

In order to plan for an orderly development of solar energy technologies, it is necessary to have information on the skill mix that may be required by the industry. Skill needs will vary considerably, both among the solar technologies and among the production stages. Research is emerging on the skill requirements of solar energy technologies, but consensus has not yet been obtained and many questions remain unanswered.

Photovoltaics

Data on skill requirements to design and manufacture photovoltaics from interviews with two major firms are presented in Table 4 [5]. These data indicate the skills currently used in the industry. At present, less than half of the labor demand is for technicians--skilled, semi-skilled, and unskilled. Most labor demand is currently for scientists, architects, managers, and support staff. Both firms devote a considerable amount of time to research and development, much of it under government contract. As the photovoltaic industry moves from research and development to commercial production, it is likely that the skill mix will change substantially.

Wind Energy Conversion Systems

Employment data from interviews with two wind energy firms are presented in Table 5. The data from the two firms are not comparable because one firm manufactures components while the other does not. The skill data indicate a relatively stronger demand for skilled technicians and machinists than was observed in the photovoltaic industry. As the industry expands and moves towards mass production techniques, labor requirements will probably shift towards a higher proportion of semi- or unskilled production workers.

Flat-Plate Collector Systems

Data on skill requirements from firms that manufacture and install five different flat-plate collector systems (primarily residential space and water heating) are summarized in Table 6. Component (pumps and controls) and collector manufacturing require relatively low skills, mainly assemblers and fabricators. Skilled crafts (51%) and technicians (24%) dominate the installation phase. Managerial/administrative, engineering, and scientific skills are required for system design, development, and wholesaling. There is also significant need for support personnel, particularly clerical.

TOTAL LABOR REQUIREMENTS

To determine total direct job requirements for design, manufacture, installation, and maintenance of solar energy systems, it is necessary to project market penetration of solar technologies. Direct labor requirements for typical systems can be multiplied by the number of projected installations to derive estimates of total job requirements.[c]

Market penetration estimates used in this exercise are those calculated by the draft Domestic Policy Review [7]. They list the potential contribution of various solar technologies by energy sector, in terms of 10^{12} Btu of oil displaced. DPR estimates of direct person-hours/MMBtu of oil displaced by solar energy are also used to calculate total employment.

DPR Scenarios

The DPR task force has estimated energy output by detailed sectors for the years 1975, 1985, 1990, and 2000. These output data have been estimated for a Base Case and a Maximum Practical Case.[d] The two cases are described as follows:

- The Base Case represents futures that would occur if current federal policies and programs and current trends in local and private action continue through the year 2000 at about the same level of committment as at present. This set of futures assumes enactment of all parts of the National Energy Act affecting conservation and renewable energy sources and examines the implications of possible differences in U.S. conventional energy prices.

- The <u>Maximum Practical Case</u> represents the maximum contribution that solar technologies could reasonably be expected to make by the turn of the century within the framework of traditional federal intervention [7].

These cases will be used as the basis for estimating the labor impacts of achieving the solar energy penetration described in them. Labor requirements will be estimated for solar technologies generating energy for non-electric use in the residential and commercial sectors and electric energy use in the utilities sector.

<u>DPR Solar Energy Estimates</u>

The DPR task force has estimated non-electric energy output for a base case and maximum practical case. The data are delineated by primary energy source (oil, gas, solar, geothermal, coal) and year (1985, 1990, and 2000). The solar energy contribution to this output is broken down by the technologies contributing to the total solar output. These data are presented in Table 7.

Potential solar energy output in the electric utility sector was also estimated by the DPR for the two cases. The data are delineated by year and by primary source of energy (coal, oil, gas, nuclear, solar, geothermal, or hydroelectric). The solar energy component of these data is also presented in Table 7.

<u>Total Direct Labor Requirements for Selected Solar Technologies</u>

Estimates of direct labor requirements for solar technologies (Table 1) are multiplied by market penetration output estimates (Table 7) to derive cumulative total employment projections.[e] Table 8 lists the direct cumulative employment estimates derived by this procedure for the years 1985, 1990, and 2000 for the Base and Maximum Practical Cases. For 2000, the range of cumulative labor requirements estimates is 766,000 person-years (Base Case) to 2.2 million person-years (Maximum Practical Case). Nineteen percent of this cumulative total is added in the year 2000. In the near-term, it is projected that most of the labor demand will be for non-electric technologies, particularly space and water heating applications.

<u>Skill Distribution</u>

An estimate of the skill distribution of solar energy employment for space and water heating systems can be derived by combining total employment data (Table 8) with the skill requirement information presented in Table 6.[f] The skill distributions required in the year 2000 under the two DPR cases are presented in Tables 9A and 9B.

For the two cases, the largest categories of skills required for solar space and water heating are managerial/administrative (25%) and skilled crafts (25%). Semi-skilled and unskilled workers (18%) and technicians (13%) are also important categories. Since solar non-electric applications are projected to make the most significant contribution, attention should be given in designing training efforts to meet the skill demands for solar space and water heating applications.

THE SUPPLY SIDE: SOLAR ENERGY TRAINING PROGRAMS

A major concern in the commercialization and diffusion of solar energy is to identify barriers and reduce or eliminate them where possible. The shortage (either regional or national) of trained, experienced manpower has been raised as one potential barrier to diffusion of new technologies such as solar energy devices and systems (Crossman et al. [8], Thomas [9], Rosenberg [10]). Experience with the New England Electric System Solar Project showed the importance of trained solar workers. In this project, 100 residential solar hot water heating systems were retrofitted. Eighty-five of the systems required some sort of repair, and most of the problems were attributed to faulty installation [11].

Despite uncertainties about the quantity and types of jobs that might be generated by solar energy commercialization, solar-related training courses and programs are rapidly being initiated across the country. Courses and curricula are currently offered (or are planned) by four-year universities and colleges, community colleges, adult and vocational education institutions, industry, unions, and federal, state, and local governments. Whether the supply of graduates from these programs will meet--or exceed--the demand of an expanding solar industry is an empirical question that is currently unanswered.

The purposes of this section are to provide a general framework for discussing solar energy education efforts and to review a limited sample of current programs. The concluding section addresses some important issues about solar energy training and how it meshes with potential demand.

Types of Solar Energy Education and Training Programs

Education and training programs in the solar energy area assume a variety of forms and are aimed at disparate audiences, from research and development personnel to the purchaser or user of the system.[g] Four broad categories of programs can be identified: general education, professional education, technician training, and education designed to develop a market infrastructure.

General education programs in solar energy are of three types. The first type is aimed at promoting basic awareness and consumer acceptance. These programs operate through the regular school system (K-12 and colleges), continuing education, the media, and workshops or conferences. The objectives of such programs are to increase awareness of energy problems, inform persons about the general types of solar systems, increase knowledge about conservation practices, and provide general information about purchasing solar systems. A number of energy education materials for grades K-12 have been developed by groups such as the National Science Teachers Association with support from the Department of Energy. These include solar energy experiments, information on energy conservation practices, and information on the role and importance of energy in society.

A second type of general education program is the more advanced, continuing education course for persons involved in public interest groups, policy development and analysis, and social research. Such programs provide general energy background and information on the technical characteristics of solar energy systems, costs and benefits of solar energy, and the effects of policy options on solar energy commercialization. These programs are often organized in the form of short workshops or conferences.

The third type of general education is the development of instructions, pamphlets, and books for do-it-yourself solar energy systems. They provide a short training course in assembly, installation, and repair for the person with general technical abilities.

Examples of courses which combine aspects of these last two types of general education are those offered by the Weston Center for Open Education, located at the Cambridge School in Weston, Massachusetts. Several non-credit courses are offered for anyone interested in solar energy—homeowners, architects, builders, and trade technicians. The courses, most consisting of seven two-hour sessions, are taught by two professional engineers. Enrollment averages about 12 students per course; between 400 and 500 people have taken courses since the program's inception four years ago.

The second broad category is education and training for professional careers in solar energy. Programs include courses offered by higher education and continuing education institutions and workshops, conferences, or short courses offered by industry. The programs seek to teach the principles of solar energy systems and the problem-defining and solving skills needed by solar energy professionals. Those involved include research and development personnel, architects, planners, engineers, and managers.

An example of a four-year degree program in solar energy technology is the bachelor of science degree offered by the Colorado Technical College in Colorado Springs, Colorado. The first two years of the program are solar technician training leading to an Associate Degree in Applied Science, whereas the last two years focus on mechanical engineering technology and lead to a B.S. degree in Solar Engineering Technology.

A graduate degree (Masters in Environmental Planning) in solar energy is offered by Arizona State University. The program requires one year of course work plus a thesis. Curricula are designed to meet the specific background and interests of each student. The program can be concentrated in either solar design or solar (engineering) technology.

A number of schools have developed courses and programs in solar energy technology. Preliminary results from a nationwide survey (conducted by SERI's Academic Programs and Information Systems branches) of 3200 postsecondary academic institutions indicate a wide variety of solar education efforts.[h] Of the 2200 respondent institutions, approximately 600 reported that they were offering at least one course in solar energy. Twenty-one institutions provide curricula leading to a degree, and 75 offer four or more solar energy courses. The 600 institutions currently offer more than 1200 courses in solar energy.

Examples of solar energy courses that are components of comprehensive professional curricula are the two courses conducted by the College of Engineering and Technology at Northern Arizona University in Flagstaff. Both courses, "Solar Energy Technology" and "Solar Engineering Analysis and Design," are aimed at engineering students. Another example is a graduate course entitled "Solar Energy Engineering," which is offered each semester by the Department of Mechanical Engineering at Georgia Institute of Technology. The course covers analytical aspects of solar design, modelling of solar processes, performance analyses, and solar system integration/control.

Several courses provide continuing education for professionals such as practicing engineers, architects, builders, and others. For example, the Solar Energy Applications Laboratory at Colorado State University in Fort Collins, in cooperation with the National Association of Home Builders, has developed two courses in solar energy. Titled "Design of Systems" and "Sizing, Installation, and Operation of Systems," these courses are intended primarily for professionals and those involved in the building industry. In the School of Continuing Education at the University of Alabama in Huntsville, three courses in solar energy are offered in evening courses for engineers: "Solar Heating and Cooling," "Solar System Analysis: Part I," and "Solar System Analysis: Part II."

Industry groups have also developed educational materials and courses for training professionals in solar heating and cooling. In 1974, Bell and Gossett ITT installed a complete solar heating and cooling system at its Morton Grove, Illinois, training facility. Fully instrumented to furnish data for ongoing research, the system also provides hands-on experience for engineers, contractors, HVAC tradesmen, and others who participate in the classes held there throughout the year. A "Solar Heating System Design Manual" for engineers, architects, builders, and students has been prepared and published by Bell & Gossett ITT.

Educational institutions, unions, industry groups, and state agencies have developed and offered technician training programs. Persons participating in the programs may be experienced trade workers or have little or no skill background. These courses generally focus on installation and service of residential and commercial solar energy systems.

A number of educational institutions offer programs leading to associate degrees in solar technology. Examples are programs offered by San Jose City College in San Jose, California and Colorado Technical College of

Colorado Springs. An associate degree curriculum in solar technology is currently being developed by Navarro College in Corsicana, Texas.

Several community colleges and vocational educational institutions offer certificate programs in solar energy. The Community College of Denver, Red Rocks Campus, provides a certificate in Solar Energy Installation and Maintenance. The nine-month program emphasizes practical, hands-on applications and is designed to prepare students for employment in solar system installation and maintenance.

Comprehensive Employment and Training Act (CETA) funds have been used to finance several solar energy training programs, most of them in California. One of the earlier efforts was conducted during the summer of 1976 at the San Jose Branch of the Center for Employment Training, which offered a course in solar fabrication and installation for 37 former migrant farmworkers. Another CETA-funded program is offered by California State University at Sonoma, which has conducted its Solar Technician Training program since 1976. The one-year program prepares the CETA participants for positions in system sizing, economic calculations, sales, consulting, or other solar-related areas.

For those unable to participate in other training programs, an accredited correspondence course--"Fundamentals of Solar Heating"--is currently providing home-study instruction in solar technology for HVAC industry employees. The course is a joint effort of the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) and the North American Heating and Air Conditioning Wholesalers Association (NHAW). Developed by the NHAW's Home Study Institute of Columbus, Ohio, the course was funded by a grant from DOE's Solar Technology Transfer Program. Based on materials provided by the Solar Energy Application Lab at Colorado State University and information from DOE and HUD, the program is intended to convey the essential information needed by heating and air-conditioning contractors to size, install, and service solar systems.

Infrastructure education programs for sales, marketing, and managers in solar energy companies require a combination of general solar education and limited technical material. Additional audiences who would be involved in the market infrastructure are personnel in financial institutions, building code and zoning officials, real estate appraisers, utility managers, media personnel, and others. The infrastructure audience appears to have received much less attention than the other education and training categories.

Two courses provided by industry specifically include distributors, dealers, and sales personnel: the Solaron training sessions held bimonthly by the Solaron Corporation of Denver, Colorado, and the training manuals developed by the Fedders Corporation of Edison, New Jersey, for dealers, sales personnel, contractors, and builders. Some professional organizations, such as the American Institute of Architects, offer solar energy information and education for their members.

CONCLUSIONS

Employment Impacts

Most research on the employment impacts of solar energy concludes that it is more labor intensive than conventional sources and that significant job opportunities will be created by solar energy adoption. Given the present configuration of solar energy technologies, this is not a surprising result. On-site applications are particularly labor intensive, since considerable labor is required for installation. But before policies promoting solar energy commercialization on the basis of job creation potential are pursued, several crucial questions should be answered.

First, most research has focused only on the direct employment impacts of solar energy and there has been little analysis of its indirect or induced employment effects. Important questions here are the secondary employment effects resulting from the purchase of inputs such as primary metals, glass, etc.; the impact of personal consumption expenditures by employees in the solar energy industry and related industries; the impact of altering the composition of demand for energy (direct and indirect consumption) and the resulting employment effects; and the reduction in employment caused by reduced demand for conventional energy due to solar energy adoption (e.g., the number of coal miner jobs lost).[i]

A second unanswered question involves uncertainties about future production techniques in solar energy systems. Labor costs currently represent 30% to 50% of total costs for residential hot water and space heating systems [14]. If solar energy is to be competitive with conventional sources, labor inputs will probably be decreased by system packaging, learning effects, mass production, and technological changes. Limited evidence suggests that reduction in labor/output ratios have already occurred. Such advances in production techniques will undoubtedly reduce the relative labor intensity of solar energy.

Finally, it is important from a policy perspective to know the geographic and skill distribution of labor demands of a solar industry. For on-site solar technologies, it is likely that jobs will be created on a dispersed basis. For centralized applications, demand will be compressed, both geographically and through time. Little attention has been given to the geographic distribution of labor demand and how that demand relates to existing regional occupational pools.

Although considerable variation exists in the research on skill requirements for solar energy, one important generalization can be ventured: flat-plate collector systems as presently constructed generally require a higher proportion of relatively low skills for manufacture while installation requires a higher proportion of skilled trades (plumbers, electricians, carpenters, etc.). The majority of total labor required to design, manufacture, and install a flat-plate collector system is in the installation phase, so much of the demand is currently for skilled trades (see Tables 9A and 9B). The same generalization is probably true for photovoltaics, although evidence is sketchy at best. For small-scale wind energy systems, basic machinist and engineering skills are required. Large-scale, centralized solar energy facilities such as solar thermal generating plants will probably demand skill levels similar to those for construction and operation of conventional generating plants.

Education and Training Issues

There appear to be two distinct but conflicting notions about the types of skills--and training--required by the solar energy industry. On one side, trade unions claim that journeyman skills are necessary to ensure quality installation and maintenance.[3] The union posture is that their members can gain sufficient knowledge about solar energy technologies by a few hours on solar energy added to their apprenticeship programs or to refresher courses for journeymen.

On the other side are those who believe that solar energy will provide jobs for the hard-core or structurally unemployed. For example, the Departments of Labor and Energy and the Community Services Administration recently initiated a pilot program entitled "Solar Utilization/Economic Development and Employment Program (SUEDE)." Its purpose is to "demonstrate the feasibility of coordinating energy conservation, job creation and training, housing and community development--all with the aim of increasing employment and small business opportunities, broadening the use of solar technology, and assisting needy families" [15]. Comprehensive Employment and Training Act (CETA) funds will pay the wages of participants, and DOE and CSA will fund equipment costs. The basic hypothesis underlying this program--one which deserves careful scrutiny--is that the solar energy industry will ultimately offer employment possibilities for CETA-eligible individuals.

As mentioned earlier, preliminary evidence indicates that installation, which tends to require skilled trades, is the most important process stage in terms of labor demand (for flat-plate collectors). The manufacturing component, which represents about 20% to 30% of total labor required, can be accomplished with relatively low skills. It therefore appears that both perspectives on training requirements hold some validity. But the trick here is to ensure that training efforts are linked closely--both geographically and temporally--to industry demand for skilled and unskilled workers.

There is little consensus about the types of training needed by the solar industry. Objectives of programs range from providing basic construction skills (with limited focus on solar energy systems) to curricula which produce highly specialized "solar technicians." It may be that diversity in training effort accurately reflects diversity in demand. But given the immature nature of the solar industry, a cautious approach to developing solar training programs seems appropriate. This recommendation is in accord with the Solar Energy Task Force Report, Recommended Technical Training Guidelines, which concluded:

In general, this Task Force does not advance a position of advocacy in technical training which produces individuals strictly known as solar technicians, mechanics, installers, etc. It is emphasized that because demand for purely solar jobs is uncertain, training a person for job entry as a strictly "solar" anything might not assure employment [16].

Another key training issue is the role of the Federal government in ensuring that solar energy commercialization efforts are not impeded by a lack of trained manpower. The range and magnitude of existing training efforts indicate that little encouragement is presently needed to develop courses and programs. Present solar training efforts involve many participants and offer many types of education. In light of this diversity, federal activities might focus on (1) providing coordination and information exchange to ensure that the right type and number of training courses are offered to meet but not exceed the projected labor demand; (2) supporting the development of curricula and educational materials that disseminate information and technological developments resulting from research and development activities; (3) conducting analyses and evaluations of current training efforts to determine what "works" in solar energy education; and (4) increasing current efforts to provide public information, consumer education, and education to help develop a market infrastructure (important audiences are financial institutions and the building industry).

In Conclusion

It appears that solar energy commercialization holds potential for creating job opportunities and, given present high unemployment rates, will have a salutary effect on the labor market. Training programs are rapidly being started across the country. Although there are no data on the number of graduates from these programs, there is a wide range of trade skill programs aimed at meeting the diverse needs of the solar industry. If these programs are effective, shortages of skilled manpower are not likely to pose a significant barrier to commercialization of solar energy technologies. However, for policy formulation and program development, it is necessary to have quantitative and qualitative information on the number and quality of program graduates over time. This information would allow policies and programs to be developed that would link the level and quantity of labor supply and demand.

The overall labor impacts of increased utilization of solar energy are difficult to assess. As the Office of Technology assessment study concludes:

> . . . in the absence of an adequate methodology, the most critical questions involving the impact of solar technologies on the work force cannot be answered with certainty [17].

Research which will provide some answers to these issues is becoming available, but much remains unresolved. The following issues remain to be addressed: (1) direct job requirements for a wide variety of solar technologies, (2) how these skill requirements differ from existing occupational pools and how they relate to regional manpower supplies, (3) indirect and displacement effects on a regional basis, and (4) the sensitivity of these results to alternative economic and policy cases and the market penetration estimates that result from these alternatives.

To conclude on a note of caution, policies to advance solar energy commercialization are often advocated on the basis that solar technologies will create job opportunities for individuals currently under- or unemployed. Despite this enthusiasm, several unresolved issues will determine whether the employment impacts are beneficial from a policy standpoint. The types and geographic dispersion of jobs created by a solar industry are important concerns. Will they be low-skill (and low-wage) jobs suitable for the structurally unemployed, or will the solar industry require highly skilled and relatively scarce trades? Moreover, demographic projections suggest that, as the post-War "baby bubble" moves through the labor market, labor shortage rather than surplus may be the dominant policy concern of the future [18]. It is imperative that these questions be addressed before programs and policies are pursued which tout the labor intensity of solar energy.

FOOTNOTES

a. The Domestic Policy Review defines direct and indirect labor requirements as follows:

<u>Direct employment</u>, or the labor input required for resource recovery, direct manufacturing, construction and general O & M associated with the energy system. For a solar heating system, direct employment includes: jobs required for collector/component manufacturing, installation, O & M and back-up power. For a power plant, it includes: plant construction, resource recovery and transportation, turbine/generator manufacturing, electric transmission and distribution.

<u>Indirect employment</u>, or the jobs produced in supporting industries required to provide materials and services for the energy system over its lifetime (mostly in the capital which goes into the solar unit or conventional power plant).

b. In order to convert the person-hours/ft^2 data into person-hours/Btu of oil equivalent, it is necessary to understand the relationship between actual Btu's and Btu's of oil displaced. The relationship is based on the actual amount of Btu's needed to generate an end-use unit of electricity: 3,413 actual Btu's are required to generate one kWh of electricity. However, due to generation and transmission heat losses, enough oil at the generating source to produce 10,400 Btu's of heat must be used in order to produce one kWh of electricity for end use. As a result, to convert Btu (actual) into Btu (displaced), Btu (actual) is divided by three. The process used to convert person-hours/ft^2 into person-hours/MMBtu (displaced) is based, in part, on this relationship.

The first step in the conversion uses the following equation:

$$\text{Person-hours/MMBtu (actual)} = (\text{person-hours}/ft^2) \div (\text{MMBtu}/ft^2)$$

where MMBtu/ft^2 = 0.82 for water heating systems, and 0.38 for water and space heating systems.

Using the appropriate person-hours/ft^2 data from Table 2 in this equation yields:

2.46 person-hours/MMBtu (actual) for water heating systems, and
4.13 person-hours/MMBtu (actual) for space and water heating systems.

In order to convert these data to a MMBtu of primary oil displaced basis, these estimates are divided by three. Performing this division yields:

0.82 person-hours/MMBtu (displaced) for water heating systems, and 1.38 person-hours/MMBtu (displaced) for space and water heating systems.

c. This procedure calculates gross rather than net jobs created by solar energy technologies. To determine net job creation, it is necessary to include indirect employment impacts, induced effects (i.e., respending), and displacement impacts of reducing employment in conventional energy industries.

d. A third scenario describes a technical limits case that is currently being developed.

e. The calculations are as follow:

Total person-years =

$$\frac{\text{(person-hours/MMBtu x DPR solar penetration estimates [MMBtu])}}{\text{person-hours/year}}$$

where a person-year = 1,900 hours.

f. The skill distribution data in Tables 9A and 9B were derived in two steps. First, the total labor requirements from Table 8 were allocated to process stages by multiplying the labor requirements total by the average percentage process stage distribution in the last column of Table 2. Second, these data were allocated among skill categories by multiplying the process stage totals by the skill-by-process-stage proportions listed in the various columns of Table 6.

g. For a more comprehensive discussion and listing of solar education and training programs, see [12] and [13].

h. Results of this survey (to be published as the Solar Energy Education Directory) will be available in January 1979, from SERI, Congressman George E. Brown's office (California), and the National Solar Heating and Cooling Information Center.

i. One study being conducted by the Council on Economic Priorities does attempt to examine some of these secondary impacts, but final results are not yet available.

j. See Organized Labor and Solar Energy, Report from Herrick S. Roth Associates to the Solar Energy Research Institute, November 1978 (draft).

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TABLE 1

UNIT LABOR REQUIREMENTS OF CONVENTIONAL AND SOLAR ENERGY TECHNOLOGIES [1]

(Person-hours per MMBtu of Oil Displaced Basis)

Technologies	Person-Hours Per MMBtu of Oil Displaced: Direct Labor	Indirect Labor	Total Labor
Conventional-Electric Utilities			
Coal			
--Low Btu	0.65	0.46	1.11
--High Btu	0.56	0.39	0.95
Oil	0.55	0.33	0.88
Gas	0.85	0.48	1.33
Nuclear	0.46	0.54	1.00
Solar Non-Electric Applications			
Water Heating	0.93	1.87	2.80
Water and Space Heating	1.43	2.87	4.30
Water Heating, Space Heating & Cooling	1.67	3.33	5.00
Passive	0.57	0.93	1.50
Solar Electric Applications			
Wind	0.26	1.23	1.49
Photovoltaic	1.41	2.22	3.63
Solar Thermal	0.73	1.96	2.69
Biomass	0.25	0.87	1.12

TABLE 2

CURRENT DIRECT LABOR REQUIREMENTS FOR NEW INSTALLATIONS OF LIQUID FLAT PLATE SOLAR HEATING TECHNOLOGIES, BY PROCESS STAGE

	Study					
	Navarro College [2]	MITRE [3]	CPPC [4]	SERI [5]	Summary Data $\bar{X}$	Summary Data %
Process Stage	Residential Solar Water Heating Systems					
Design	0.20	0.323	-	0.45	0.32	16
Mfg.	-	0.280	0.247	0.27	0.27	13
Wholesale	-	-	-	0.59	0.59	29
Installation	1.0	0.597	0.80	0.79	0.80	40
Maintenance	0.04	-	-	-	0.04	2
TOTAL	1.24	1.200	1.047	2.10	2.02	100
	Residential Solar Space and Water Heating Systems					
Design	0.10	0.264	-	0.45	0.27	17
Mfg.	-	0.479	0.151	0.27	0.30	19
Wholesale	-	-	-	0.27	0.27	17
Installation	0.44	1.065	0.320	0.89	0.68	44
Maintenance	0.05	-	-	-	0.05	3
TOTAL	0.59	1.808	0.471	1.88	1.57	100

TABLE 3

LABOR-OUTPUT RATIO CHANGES FOR SOLAR HEATING SYSTEMS (NEW) [5]

(person-hours/ft^2 of collector)

System and Process Stage	Labor/Output Ratios 1976	1977	1978	Change in Total Output 1976-1978
System A				
Design, Fabrication and Sales	NA	0.81	0.56	+ 180%
Installation	NA	0.98	0.70	+ 60%
System D				
Design/Development	0.53	NA	0.23	+ 212%
Wholesale (Distribution)	NA	1.41	0.85	+ 67%
Wholesale (Distribution)*	NA	0.68	0.21	+ 221%
Installation	3.38	2.74	1.58	+ 400%

NA = Not Available

*Two firms wholesaling System D.

TABLE 4

CASE STUDY PHOTOVOLTAIC EMPLOYMENT DATA [5]

Employment Group	1978 Both Firms	% Skill Group in Each Firm Firm A	Firm B	Specific Occupations Employed
Total Employment	324	100	100	
Engineer and Scientists	68	27	18	Electrical/Electronics, Solar Mechanical, Industrial, Other Mechanical, Physicists, Chemists
Other Professional and Support	133	27	41	Managers, Marketing, Architects, Clerical, Secretarial
Technicians, Skilled, Semi-skilled, and Unskilled	123	46	40	Draftsmen, Quality Control, Electricity/ Electronics, Mechanical, Other Technicians; Electricians, Mechanics, Assembly Workers

Source: [5]

TABLE 5

WIND SYSTEMS--TWO CASE STUDIES [5]

I. Firm A: Manufactures components; designs, fabricates, and installs systems.

Labor Requirements: Manufacturing, design and fabrication requires 100 person-hours per unit (1 kw machine) including machinist, semi-skilled (for assembly), and mechanical and electrical engineer for design and evaluation. Installation requires 14-16 person-days (7-8 calendar days) including one engineer and one semi-skilled worker.

II Firm B: Designs, fabricates, and installs systems. Recently, has increased employment for design and development contract work.

	1975	1976	1977	1978
Output (2-3 kw systems)	10	25	25	25
Total Employment (person-years)	8	11	14	18
Manager/Administration	1	2	2	2
Other Support	1	2	2	3
Technicians	5	6	8	11
Draftsmen	0	0	0	2
Electric/Electronic	1	1	1	1
Mechanical	0	1	1	2
Solar	4	4	6	6
HVAC Craftsmen	1	1	2	2

TABLE 6

1978 EMPLOYMENT BY SOLAR COLLECTOR INDUSTRY STAGE--5 CASE STUDIES [5]

Occupation Group	Component Manufacture	System Design & Development	Collector Fabrication	Wholesalers, Installation Supervisors	Installation
Total Employment	100%	100%	100%	100%	100%
Engineers & Scientists (e.g., solar-mechanical, mechanical)	--	24%	1%	3%	--
Managerial/Administrative; Other Professional (e.g., supervisor, sales, accounting, purchasing)	--	49%	10%	47%	17%
Other Support (e.g., secretarial, clerical)	--	21%	3%	32%	2%
Technicians (e.g., solar, solar-sheet metal, quality control, electrical-electronic, mechanical, draftsmen	--	6%	1%	6%	24%
Skilled Crafts (e.g., sheet metal, plumber, solar mechanic, HVAC, carpenter)	--	--	--	13%	51%
Semi-skilled, Unskilled (e.g., assembly, general laborer, material handler, construction labor)	100%	--	85%	--	5%

Note: While the case studies were chosen to be representative, the employment mix percentages in the table are based on unweighted data estimates. Weights could not be computed for some reporting units that did not state output data.

Source: [5]

TABLE 7

BASE AND MAXIMUM PRACTICAL CASE SOLAR ENERGY OUTPUT

(10^{12} Btu oil displaced)

	Scenario									
	Base Case						Maximum Practical			
	1985	%	1990	%	2000	%	1990	%	2000	%
Solar Electric	8.4	100	35.4	100	734.3	100	141.3	100	2823.9	100
Wind	5.6	66	28.3	80	587.4	80	74.2	52	1509.5	54
Photovoltaic	0.9	11	2.4	7	48.9	7	22.2	16	435.2	15
Solar Thermal	1.9	23	4.7	13	98.0	13	44.9	32	879.2	31
Solar Non-Electric	10.0	100	44.0	100	900.1	100	335.5	100	2001.1	100
SHACOB Water Heating	3.4	34	14.6	33	298.9	33	111.8	34	669.9	33
SHACOB Water and Space Heating	5.5	55	24.8	56	505.6	56	185.3	55	1115.2	56
SHACOB Water Heating and Space Heating and Cooling	1.1	11	4.6	10	95.6	11	38.4	11	216.0	11

TABLE 8

BASE CASE AND MAXIMUM PRACTICAL CASE ESTIMATES OF

CUMULATIVE DIRECT PERSON-YEAR PER YEAR NEEDS OF SOLAR TECHNOLOGIES

	Scenario					
	Base Case			Maximum Practical Case		
	1985	1990	2000	1985	1990	2000
Solar Electric Technologies	2,157	7,435	153,807	2,157	43,747	864,795
Wind	763	3,858	80,072	763	10,115	205,769
Photovoltaic	668	1,781	36,289	668	16,475	322,964
Solar Thermal	726	1,796	37,446	726	17,157	336,062
Solar Non-Electric Technologies	6,783	29,909	611,980	6,783	228,346	1,359,563
Water Heating	1,670	7,169	146,776	1,670	54,900	328,956
Space and Water Heating	4,148	18,704	381,328	4,148	139,755	841,095
Water Heating and Space Heating and Cooling	965	4,036	83,876	965	33,691	189,512
Passive	597	2,925	58,789	597	49,120	298,421
TOTAL	8,940	37,344	765,787	8,940	272,093	2,224,358

TABLE 9A

SKILL REQUIREMENTS FOR SOLAR WATER AND SPACE HEATING

FOR BASE CASE DPR SCENARIOS CUMULATIVE TO 2000

Base Case 2000

Skill Class	Design	Fabrication	Wholesale	Installation	Maintenance	Total	%
			Process Stage				
Engineers and Scientists	15,558	725	1,945			18,228	5
Managerial/ Administrative and Other Professional	31,764	7,245	30,468	28,523		98,001	25
Other Support	13,613	2,174	20,096	5,034		40,917	11
Technicians	3,890	724	3,890	40,268		48,772	13
Skilled Crafts	—	—	8,427	85,570		93,997	25
Semi-skilled, Unskilled	—	61,584	—	8,389		69,973	18
Unspecified					11,440	11,440	3
TOTAL	64,825	72,452	64,825	167,784	11,440	381,328	100

TABLE 9B

SKILL REQUIREMENTS FOR SOLAR WATER AND SPACE HEATING

FOR MAXIMUM PRACTICAL CASE DPR CUMULATIVE TO 2000

	Maximum Practical Case in 2000						
	Process Stage					Summary Data	
Skill Class	Design	Fabrication	Wholesale	Installation	Maintenance	Total	%
Engineers and Scientists	34,317	1,598	4,290	—		40,205	5
Managerial/ Administrative and Other Professional	70,063	15,981	67,203	62,914		216,161	25
Other Support	30,027	4,794	44,326	11,102		90,249	11
Technicians	8,579	1,598	8,579	88,820		107,576	13
Skilled Crafts	—	—	18,588	188,742		207,330	25
Semi-skilled, Unskilled	—	135,837	—	18,504		154,341	18
Unspecified					25,233		3
TOTAL	142,986	159,808	142,986	370,082	25,233	841,095	100