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ABSTRACT

The solar energy labor force is analyzed by identifying the importance of education and training in the commercialization and diffusion of solar technologies, discussing issues for planning and analysis of solar education and training efforts, and illustrating the range of programs and courses presently available. Four general perspectives are reviewed concerning the diffusion of such a new technology as solar energy systems, with special attention to the education and training issues. Planning and analysis issues discussed include the following: whether there is a need for more education and training programs, and of what kinds; the possible roles of the federal and state governments; the availability of trained workers for the manufacture of solar systems; the tradeoffs between expanding the capabilities of persons already within the field or training unemployed and underemployed persons as solar workers; and the allocation of effort between training workers and training trainers. Examples of programs and courses are given for the four identified categories: general education, professional solar energy education and training, technician training, and solar industries infrastructure training. The general conclusion is that a large number and variety of education and training programs and courses are presently offered, but that little or no evaluation of individual programs or the overall effort has yet been done. (Author/CT)

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THE ROLE OF EDUCATION AND TRAINING PROGRAMS IN THE COMMERCIALIZATION AND DIFFUSION OF SOLAR ENERGY TECHNOLOGIES

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NOTICE

FOREWORD

This report documents preliminary work on Task 5379.10. Persons contributing to this paper were Barbara Burns, Bert Mason, and Keith Armington of the Institutional and Environmental Assessment Branch, Analysis and Assessment Division.

An earlier draft was reviewed by a number of SERI colleagues: Mel Simmons, David Roessner, Barbara Farhar, Robin Saltonstall, George Corcoleotes, and Charles Unseld. Their comments have significantly improved the accuracy and completeness of the paper. Any remaining errors or ommissions are the responsibility of the authors.

Dennis Schiffel, Branch Chief

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Abstract

An important part of analyzing employment and labor force requirements in the solar energy field is determining the availability of trained and experienced workers and of programs to provide additional training.

This paper provides a base for analysis of these labor force supply questions by identifying the importance of education and training in the commercialization and diffusion of solar technologies, discussing issues for planning and analysis of solar education and training efforts, and illustrating the range of programs and courses presently available.

The paper reviews four general perspectives on the diffusion of a new technology such as solar energy systems, with special attention to the education and training issues.

Planning and analysis issues discussed include: whether there is a need for more education and training programs, and of what kinds; the possible roles of the federal and state governments; the availability of trained workers for the manufacture of solar systems; the tradeoffs between expanding the capabilities of persons already within the HVAC field or training unemployed and underemployed persons as solar workers; and the allocation of effort between training workers and training trainers.

Examples of programs and courses are given for the four categories identified: general education, professional solar energy education and training, technician training, and solar industries infrastructure training. The general conclusion is that a large number and variety of education and training programs and courses are presently offered, but that little or no evaluation of individual programs or the overall effort has yet been done.

SECTION 1.0

INTRODUCTION

Solar energy may hold the potential for supplying a significant portion of the nation's energy needs in the future. A recent report by the Council on Environmental Quality predicts that one quarter of all U.S. energy could be supplied by solar technologies by the year 2000 [1]. A second report by the Office of Technology Assessment (OTA) suggests the importance of solar technologies could grow substantially over the next ten years [2]. The Domestic Policy Review of Solar Energy estimated that in the year 2000, solar energy technologies could displace between 9.4 and 18.1 quads of energy supplied by other fuels (estimates for the Base Case of $25/bbl and for the "Maximum Practical" Case) [3]. The optimistic outlooks of these reports, however, assume that publicly funded efforts will encourage solar energy commercialization, and that barriers to diffusion of solar energy technologies can be overcome or minimized.

A number of policies and programs have been developed at the state and national level to accelerate the commercialization of solar technologies. Over half of the states offer some form of solar property tax incentive, and 23 states are supporting solar energy research, development, and demonstration projects [4]. The National Energy Act of 1978 provides significant personal and corporate income tax credits for investments in solar energy systems. These federal and state incentive programs are intended to stimulate the growth of both the solar energy industry and the solar purchaser market.*

One major concern of policymakers charged with promoting the commercialization and diffusion process is to identify barriers and reduce or eliminate them where possible. The shortage (either national or regional) of trained and experienced manpower has been raised as one possible barrier to diffusion of new technologies such as solar energy devices and systems [5,6,7,8]. The extent of consumer acceptance (and, therefore, of market penetration) of solar energy technologies may depend in part on the availability of trained manpower to manufacture, install, and maintain solar systems.

*While much of the general discussion in this paper is meant to apply to the broad range of solar energy technologies (e.g., biomass, photovoltaics, ocean thermal, solar heating and cooling), most of the specific examples focus on solar space and water heating applications. This focus accurately reflects the current status of education and training efforts; the vast majority of programs concentrate on the space and water heating applications.

Experience with the New England Electric System Solar Project showed the importance of trained solar workers in the diffusion of domestic hot water heating systems. In this project, the utilities sponsored the retrofit of 100 solar hot water heating systems. Fifteen of the installations worked well. Of the rest, 8 had no serious breakdown, 57 had at least 1 major stoppage or breakdown requiring repair by technicians, and about 20 provided severely interrupted and unreliable service. Most of the problems were attributed to installation flaws. The installers and manufacturers of the 15 systems which operated well were among the most experienced with solar systems. None of the installations were supervised by experienced solar system engineers. In general, the installations would have satisfied standards for conventional systems but were inadequate for solar systems [9].*

A second policy concern is to understand and prepare for changes in labor market conditions and job skills which may result from diffusion of solar energy technologies. There is considerable variation among estimates of direct labor requirements for solar energy technologies. In addition, most of the existing studies do not take into account the indirect labor requirements, the geographic dispersal of the job changes, and the extent to which jobs will be created for individuals presently under- or unemployed [7].

A third major concern is for coordination and information exchange among existing solar education and training programs. The present solar training effort involves many actors (federal government, community colleges, unions, industry, universities). There appears to be a need for 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. Despite uncertainties about the labor and skill requirements of solar energy technologies, training programs on solar technology are rapidly being initiated across the nation. Preliminary estimates from a national survey of educational institutions are that about 700 educational institutions are offering some form of solar study. There are approximately 150 curricula or programs offered, 36 of which are at the graduate level.**

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*According to Edward Carlough, President of the Sheet Metal Workers Union, none of the installations were done by union members (comments at Labor Leadership Workshop on Solar Energy Commercializations, Silver Spring, Maryland, June 9, 1978).

**The Congressional Solar Coalition, with cooperation from the SERI Academic Programs Branch, has completed a national survey of solar courses and programs offered by educational institutions. The results of this survey are reported in <u>The 1978-79 National Solar Energy Education Directory</u>, to be available through the U.S. Government Printing Office in February 1979.

One of the U.S. Department of Energy's (DOE) responsibilities is to identify the appropriate role of educational institutions and activities with regard to energy matters, not only to increase public understanding of the energy situation, but also to help ensure that the necessary manpower is available to address the energy challenges of the future [10]. To this end, DOE is involved in a variety of programs supporting energy-related education in the United States. The five principal areas of involvement by DOE and its predecessor agencies are: (1) training, (2) curriculum development, (3) special educational events, (4) facilities support, and (5) the Energy Extension Service [10].

Part of SERI's mandate is to provide support to the national program to develop and commercialize solar energy technologies. Two specific functions are to "provide planning support to DOE in the development of national solar energy policies" and to "conduct market analyses and assessments of institutional barriers to the introduction of solar technologies." As part of these functions, the Analysis and Assessment Division of SERI has developed a task to address the labor, manpower, and training requirements of solar energy technologies. The major objectives of that task as described in SERI's FY79 Annual Operating Plan are:

- to review and provide critical analysis of programs addressing the manpower and training requirements of selected solar energy technologies;
- to provide support for DOE program activities which relate to solar employment and training;and
- to provide analytical support to the Academic and International Programs Division of SERI [11].

This paper and a compendium of solar training and education courses [12] are the first output of the training portion of the task. The purposes of this paper are to identify the role of training and education programs in the commercialization and diffusion of solar technologies, and to specify issues which will need to be addressed by those responsible for developing and evaluating solar education and training policies and programs.

The paper discusses four general perspectives on the diffusion of a new technology such as solar energy systems, explores the role of education and training programs in the diffusion of technological innovations generally and solar energy technologies in particular, identifies a number of policy issues concerning solar education and training programs, and cites examples of some ongoing and proposed programs in solar heating and cooling.* We are reviewing

*A related project is addressing the labor and skill requirements for solar energy technologies. The initial framework for that project is presented in Mason and Armington (1978). [7]

these four diffusion perspectives in order to build on the variables and relationships which researchers have identified as important in the diffusion process. From studies of other innovations, we hope to define the role(s) of education and training programs in the diffusion process. We will also ask whether the research on diffusion provides any insight useful for the development of educational and training programs. Although we are concerned about the importance of education and training relative to other factors influencing diffusion, neither the data nor the theory are sufficient to measure relative importance.

SECTION 2.0

THE ROLE OF EDUCATION AND TRAINING IN THE DIFFUSION OF INNOVATIONS

The diffusion of innovation refers to the process by which new ideas or products spread among individuals and/or organizations in a social system. Commercialization is a subset of the diffusion process, concerned with the establishment of a viable private demand for a product or system and an industry able to meet this demand [13]. The literature on diffusion of innovations is extensive and addresses specific products purchased or used by individuals, the spread of political and social ideas in a society, and the adoption of new processes by firms and industries. Education and training are discussed in the literature as they affect the willingness of individuals to adopt new technologies and as they train the persons needed to manufacture, provide, and service innovations.

A recent overview of approaches to diffusion research is found in a paper by Lawrence A. Brown [14]. He identifies and discusses four major approaches to diffusion research: the adoption, market and infrastructure, economic history, and development perspectives. According to Brown, the adoption perspective focuses on "the process by which adoption of the innovation occurs, (or) the <u>demand</u> side of diffusion." The market and infrastructure perspective addresses "the process by which innovations and the conditions for adoption are made available to potential adopters, (or) the <u>supply</u> side of diffusion." The economic history perspective is concerned with "the preconditions for diffusion whereby the innovation is <u>adapted</u> to the needs and situations of potential adopters." The development perspective deals with "the social and economic consequences of the diffusion of a given innovation and the interrelationship between social and economic change, development, and diffusion" (p. 4-5). Each of these four approaches treat the training and education issues differently. For each approach, the relevance to solar education and training issues will be discussed.

2.1 THE ADOPTION PERSPECTIVE

The adoption perspective is the traditional approach to diffusion research and constitutes the largest body of literature. It also has had the most use in developing and analyzing public policy [14, 15]. One example is the use of this approach in the development and continued evaluation of the Agricultural Extension Service.

The research on diffusion and adoption of innovations was collected and analyzed by Everett Rogers in 1962, and updated by Rogers and Floyd Shoemaker in 1971 [16]. The central theme of their book is the importance of communication in the entire social change process. Rogers and Shoemaker describe diffusion as the process by which information about new ideas or products is communicated to the members of a social system; social changes may result from the adoption or rejection of the idea or product. While changes in knowledge or attitudes may result, the primary measure of diffusion is whether a behavior change has occurred. Based on their analysis of existing research, Rogers and Shoemaker defined the five most important characteristics of innovations, as perceived by the adopters, which influence the rate of adoption: (1) relative advantage in economic and noneconomic terms; (2) compatibility with existing values and past experiences of the receiver; (3) complexity; (4) trialability, or the degree to which the innovation can be tried on a limited basis; and (5) observability, or the visibility of the innovation's results to others.

The primary disciplines surveyed by Rogers and Shoemaker were anthropology, sociology, rural sociology, education, medical sociology, communication, and marketing. Economics, psychology, geography, and other disciplines with small amounts of diffusion literature were also covered. Eight main topics in diffusion research were identified: rate of adoption in a social system, rate of adoption in different social systems, perceived attributes of innovations, characteristics of innovators, earliness of knowing about innovations, characteristics of opinion leaders, use of communication channels, and consequences of innovation. Rogers and Shoemaker identified the shortcomings of the existing research at that time as (1) the difficulty of taking into account the fact that diffusion occurs over time, with no clear beginning or end, (2) emphasis on the nature of the innovation itself rather than the general process and the theory, (3) the focus on optional decisions by the individual rather than on decisions with a collective or authority nature and on individual adopters rather than adoption by communities or organizations, (4) the use of the individual as the unit of analysis rather than the relationships among individuals, and (5) the concentration of studies on modern societies (i.e., the United States and Western Europe) rather than on traditional systems.

Of primary concern in the adoption perspective is the innovativeness of individuals and the factors which influence innovativeness. Work by Hagerstrand in geography* expanded the concept of innovativeness to include social and economic resistance of individuals. According to Hagerstrand, social resistance occurs when adoption of the innovation would be inconsistent with the individual's values. Economic resistance results from practical factors which make adoption difficult or impossible. Levels of social and economic resistance vary as a function of personal and group characteristics,

*A discussion of Hagerstrand's conceptual model of the innovation diffusion process and later modifications of his work can be found in L.A. Brown (1977) and L.A. Brown (1978). Hagerstrand's 1953 book has also been translated from Swedish by A. Pred as Innovation Diffusion as a Spatial Process, University of Chicago Press, 1967.

with higher levels of resistance requiring more information for adoption to occur [14]*.

The literature collected by Rogers and Shoemaker primarily addresses specific innovations adopted by individuals or communities (e.g., flouridation). The adoption perspective has also been applied to adoption of innovations by firms [17]. Instead of focusing on communication channels and messages, the important variables are the proportion of firms already using the innovation, the profitability of using the innovation, and the investment required to install the innovation.

The work done within the adoption perspective is particularly useful for designing and assessing the effectiveness of solar education programs for the general public and for potential adopters. These include mass media or educational institution efforts to provide a general understanding of solar energy, public or private programs to encourage consumer acceptance and purchase, and programs to promote industrial adoption. Particular contributions of the adoption perspective include defining the characteristics of an innovation which influence the rate of adoption, the structure of information networks, the role and characteristics of opinion leaders, and the significance of different media as a function of the point on the diffusion curve and the type of technology**.

The adoption perspective does not address the institutional or technical barriers to the diffusion process. For this, we need to explore the next two perspectives discussed.

2.2 THE MARKET OR INFRASTRUCTURE PERSPECTIVE

The market or infrastructure perspective on diffusion research was developed to handle discrepancies between Hagerstrand's model and observed reality [18, 14]. This model of the innovation process is composed of three

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*A planned study in the Analysis and Assessment Division of SERI will explore the factors influencing the individual's energy-related decisions. For a research plan, see Farhar, Barbara C., Charles Unseld, Patricia Weis, and Barbara Burns, Social Dimensions of Solar Diffusion, Technical Progress Report, (draft) SERI, November 1978.

**Extensive work in the adoption of innovations has resulted in a graphic representation of the rate of diffusion over time. It is referred to as the diffusion curve or the S-curve. A discussion of this curve and its use and form in market penetration models can be found in Schiffel, Dennis, Dennis Costello, David Posner, and Robert Witholder. The Market Penetration of Solar Energy: A Model Review Workshop Summary, Golden, Colorado: SERI-16, January 1978.

activities: the establishment of diffusion agencies, establishment of the innovation, and adoption of the innovation. Particular attention is focused on the supply side of diffusion by addressing the characteristics and role of the diffusion agencies. Agencies are categorized by their organizational structure, with the extremes being a mononuclear (or highly centralized) propagation structure and a polynuclear (or fragmented) structure [14]. The approach is unique in the diffusion literature because it focuses on the agencies that handle the diffusion of the innovation. The approach recognizes both the supply and demand side of diffusion, the creation and use of an infrastructure, and the marketing of the innovation. At present, the solar industry and the solar education and training effort are fragmented or polynuclear. Examples of present diffusion agencies for solar energy are the Department of Energy, the regional solar energy centers (NESEC, MASEC, Western Sun, and the Southern Regional Office), the national SERI, the Solar Energy Industries Association (SEIA), and the International Solar Energy Society (ISES). Agencies involved in the diffusion of solar technologies will probably grow rapidly over the next few years. As such, the growing infrastructure will demand persons trained in areas such as research, marketing, education, and management who have a knowledge of solar energy.

In this perspective on diffusion research the adoption decision is also tied to the presence and characteristics of the infrastructure. Two sets of factors are thought to influence the decision and behavior of the potential adopter: (1) "the potential adopter's need or desire for the innovation and his ability to obtain it," and (2) "(the) infrastructure that enables or enhances the subsequent use of the innovation and generally is made available through the actions of persons other than the adopter" [14, 13]. In the case of residential solar systems, for example, the infrastructure would include the sales, service, and repair organizations. To the extent that utilities adopt solar energy as a source of grid power, the established utility infrastructures would apply. Brown sees the infrastructure factors as important for only some innovations and, in those cases, feels that their absence may constrain diffusion. In the market and infrastructure approach, only a few of the factors controlling innovation diffusion relate to communications and innovativeness, which are cited by other approaches as primary factors in the adoption perspective. This approach also sees diffusion as having a variety of patterns which cannot be explained by a single process, with phenomena proposed by some researchers as empirical regularities of diffusion (such as S-curves) occurring only under certain circumstances.

Within the solar energy area, this perspective has been incorporated into the concept of a technology delivery system (TDS). As charted by Ezra [19] and a report for DOE [20], the TDS ranges from the research organizations to the end consumers, including such institutions as trade and manufacturers' associations, realtors, labor unions, and taxing authorities. Ezra includes technical information and manpower needs, but does not explicitly treat education and training needs. The DOE report includes media, public education and information, and training for installation and maintenance. Education for solar professionals such as engineers and architects and for those involved in the infrastructure (e.g., market research, sales, distribution, financial institutions) is not explicitly included.

2.3 THE ECONOMIC HISTORY PERSPECTIVE

A third perspective on diffusion research is that of the economic historian [21, 8, 14]. Innovation is considered to be a continuous process involving many technical changes rather than a discrete technological phenomenon. The approach allows for a gradual transition from the "old" to the "new" technology, including a period of "back-up" systems, the improvement of the technologies to be "replaced," and the continued development of the new technology. Because of these characteristics, this approach is the most descriptive of the diffusion of solar energy technologies.

Rosenberg [8] identifies seven factors which have historically played a significant role in the innovation diffusion process. The first, and most important, of these factors is the continuity of inventive activity, i.e., the gradual development of the innovation. Treating innovations as sharp discontinuities in technological development ignores the continued improvements and modifications that are made during the diffusion period. Rosenberg states that even major technological breakthroughs have a much more gently declining slope of cost reduction than one would expect from the literature. The process of implementing the technique or adopting the innovation also consists of a series of small steps, with the former technology retained until the new one has proven itself.

Rosenberg feels that this factor is particularly important because the present definition of innovations as discrete phenomena distorts the view of the diffusion process. As he states, "...we are led to treat the period after the conventional dating of an invention as one where a fairly well-established technique is awaiting adoption whereas, in fact, highly significant technological and economic adaptations are typically waiting to be made" [8, p. 4]. The solar energy technologies illustrate this factor fairly well. The technologies are undergoing continual development and improvement. It is likely that the transition from conventional energy supplies to alternative sources--even if solar energy becomes clearly cost-effective--will be a gradual process, both in time as well as technological development.

A second but related factor is the improvement made in the invention after it is initially introduced. New inventions are often crude and may represent only a minor or questionable improvement over existing techniques. Therefore, diffusion may be slow. Rosenberg cites studies of railroad technology, which attribute more increase in productivity to the improvement of an innovation than to the initial development. Solar energy is still a developing field of technology and important improvements are likely to occur, particularly in solar electric systems.

The third factor is the development of skills among users of the innovation. Rosenberg feels that learning curves within an established technology are well recognized, but that "the role of learning experiences in accounting for the gradual improvements of new technologies and their slow diffusion has not received much attention" [8, p. 8]. In some cases, he points out, the skills are acquired on the job and cannot be easily transferred through formal education. Diffusion in these cases relies on the movement of knowledgeable and trained persons. This is the most explicit treatment of training and education in the diffusion literature. Unlike Rosenberg's example, solar training includes both formal education (principles of design and sizing, for example) and on-the-job experience (seeing what really works in different situations). Following Rosenberg's reasoning, however, the rate of diffusion of solar technologies may increase as trained solar workers become more available and as designers and installers gain experience and a reputation for reliable performance of their systems.

The fourth factor is the development of skills in machine-making. In the past, numerous inventions had to await the development of appropriate machinery and techniques before actual production and diffusion could take place. Even today, the diffusion of a technological development may depend upon conditions in the capital goods industries and improvements in production processes.

The fifth factor concerns complementary inventions which increase the possibility that the new techniques will be diffused. In many cases, bottlenecks are encountered which require additional inventive activity. Rosenberg cites the numerous railroad innovations between 1807 and 1910 as an example of this complementarity.

These last two factors do not appear to pose major barriers to the commercialization of solar space and water heating systems. For solar electric technologies, however, a more complex technological advance is required. The commercial success of photovoltaics, for example, depends on technical or production process breakthroughs to reduce the price per kilowatt to the competitive range.

Rosenberg identifies the sixth factor which may slow the diffusion of the innovation as the continued improvement of the "old" technology. In many studies, he says, interest in the old technique ends as soon as the new one is introduced. In reality, improvements continue to be made in the existing technologies which may slow the diffusion of the new technique. Rosenberg suggests that this push from an innovation may cause more improvement in existing techniques than do the regular pressures of competition. The current energy situation is an example of the importance of this variable. Projecting the market penetration of solar energy technologies must take into account current developments in other energy technologies, such as increased efficiency of conventional heating systems, increased home insulation, improved heat pumps, and recovery of oil and gas from shale and coal veins.

The last factor defined by Rosenberg is the uncertainty in the innovation process. By this he means "...the uncertainty generated not only by technological innovations elsewhere in the economy, but by further improvement in the technology whose introduction is now being considered" (p. 17). The adoption decision may be adversely affected by a high rate of innovation, i.e., if the adopter expects further significant improvements in the new technique or even yet other new techniques, he may be reluctant to adopt the new technique. In these situations, a decision to invest in the new technique may soon be obsolete. An example of this uncertainty in the solar energy field is the possibility that investment in silicon technology for photovoltaic cells will be made obsolete by the results of advanced R&D programs. Additionally, the proliferation of similar technologies makes it difficult to make a fully informed decision to adopt. These comments will undoubtedly sound familiar to many homeowners who feel that the solar technologies will probably improve, and that they should wait to see what improvements are made and whether the costs decrease. In the case of builders, contractors, and the HVAC trades, the continuing changes in and wide variety of solar energy systems make it difficult to justify the personal investment needed to become knowledgeable about any one technology. This difficulty extends to training, where individuals ask to what extent they should train for specific solar energy systems that might be obsolete in a few years.

2.4 THE DEVELOPMENT PERSPECTIVE

The fourth perspective on diffusion research is the development perspective. This perspective "...considers both the role of the level of development in the diffusion process and the impact of diffusion practices upon individual or collective welfare" [14, p. 27]. This approach has grown out of traditional adoption perspective, modified by the results of field studies in developing societies and the insights gained from the market and infrastructure model. In particular, the development approach incorporates resources such as information and capital, and their distribution through means such as public infrastructures and services. This approach also considers the way in which the characteristics of the infrastructure affect individual innovativeness and entrepreneurship, a relationship which appears more strongly in the field studies of developing societies than in earlier diffusion research.

The communication model used in this approach, as in the adoption perspective, is the two-step flow of communications. The development perspective shows this communication pattern more clearly. Messages are directed from the diffusion agencies to the opinion leaders in the population, who then pass the information on to the general population. In solar heating and cooling these opinion leaders include builders, architects, mortgage bankers, real estate agents, the HVAC trades, developers and others. These people are not only part of the solar energy infrastructure, but are also information sources for individuals considering the purchase of a solar system.

Other important concepts in the development approach are adoption rent or the differential benefits gained by early vs. later adopters; the differential benefits for adopters vs. non-adopters; and the categorization of innovations as benefitting large-scale or small-scale operations and as labor-augmenting vs. material-augmenting. The first two of these concepts may be useful in studying the adoption of solar energy technologies, but the last concept is the only one directly relevant to employment and training analyses.

2.5 SUMMARY

At present, there are two major needs to be met to encourage the diffusion and commercialization of solar technologies and systems—a need to provide incentives to increase the likelihood that consumers, businesses, and utilities will adopt solar energy systems (the demand side), and a need to ensure that the innovation is available and competitive, and that maintenance and other services are available (the supply side). The adoption and development perspectives are aimed at the adopter of the innovation, and are useful in developing public programs to educate potential purchasers of solar technologies. These perspectives are also useful in identifying causes of individual resistance to adoption, and in developing information programs or incentives to reduce the resistance. These two perspectives do not, however, address the institutional mechanisms for or barriers to diffusing the innovation. For those questions, the market and infrastructure perspective and the economic history perspective are more relevant.

The role of education and technical training in the diffusion process is handled explicitly only by the economic historians. As discussed earlier, this includes the development of skills among users and skills in machine making. The shortage of needed skills is clearly identified by economic historians as a barrier to diffusion or as a braking influence on the rate of diffusion. The market and infrastructure approach, as described by Brown, does not explicitly handle training and education questions, but there are a number of ways in which these issues are implicit. For example, trained persons are needed to establish and operate the diffusion agencies, and to provide the personnel for the infrastructure. The discussion of the TDS for solar energy does include some of the training and education issues. In general, education and training are needed for the people involved in the manufacture and assembly, the marketing and communications, and the delivery and maintenance of the innovations. Table 2-1 relates the areas of education and training we have discussed to the major components of the innovation diffusion process.*

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*As SERI's work in this area continues, it may be useful to integrate the education and training needs with the complete solar energy TDS. That level of detail is beyond the scope of this paper.

Table 2-1 EDUCATIONAL AND TRAINING PROGRAMS IN THE DIFFUSION PROCESS

COMPONENTS OF DIFFUSION PROCESS	PARTICIPANTS IN EDUCATION AND TRAINING PROGRAMS
Development and Production of the Innovation	Research and Development Personnel Systems Designers System Engineers Skilled Manufacturing Workers
Development of Infrastructure to Provide and Service Innovation	Marketing and Sales Managers Builders and Developers Financial Institutions Installation Workers Service Managers and Workers Real Estate Brokers and Assessors Architectural and Engineering Firms
Development of the Markets	General Public Organizational and Institutional Decision Makers

SECTION 3.0

FEDERAL TRAINING AND EDUCATION PROGRAMS TO FACILITATE DIFFUSION OF TECHNOLOGICAL INNOVATIONS

The major areas in which the federal government has traditionally supported education and training programs to facilitate the diffusion of technical innovations are medicine and education. As a result these areas have generated most of the literature on evaluation of training programs. Other large-scale training programs supported by government funds (e.g., MDTA, CETA) were developed primarily to improve the employment prospects of individuals, not to diffuse innovations.

A limited number of existing programs by DOE and the Department of Labor (DOL) have addressed the education and training of persons involved in the diffusion of energy technologies. Training programs have been implemented to provide needed skilled workers for nuclear energy development (the Technology and Training program in Oak Ridge) [22] and for solar planning and installation (CETA programs in California).* The Solar Technology Transfer Program (STTP), implemented in Fiscal Year 1977, is a major DOE effort to encourage the development of the solar energy industry through commercialization of early-impact solar applications. One of the program objectives is to develop and implement a broad range of educational programs. Accordingly, STTP established the Installer Training and Education Program, "aimed at ensuring the early availability of competent solar equipment installers for the solar industry" [23].

In addition, the STTP provides technical assistance to the Energy Extension Service (EES) program authorized by Congress and implemented in September, 1977. The ten states currently participating were selected on a competitive basis (Alabama, Connecticut, Michigan, New Mexico, Pennsylvania, Tennessee, Texas, Washington, Wisconsin, and Wyoming). Each of the ten states has received a grant of approximately $1.1 million to provide the public with technical energy-related information and to encourage the use of solar and other renewable energy resources [24]. The 19-month pilot project allows each state to design, develop, and implement its own particular program, with varying emphasis on education-related activities, thus establishing communication channels at a local level.**

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*Two well-publicized CETA solar energy training programs in California are at the San Jose Branch of the Center for Employment Training and at California State at Sonoma (formerly Sonoma State College).

**Thirty-nine states and six territories have received $30,000 grants from DOE to prepare for an expansion of the EES to a nationwide program.

The newest program was announced in August, 1978, by DOE, the Department of Labor, and the Community Services Administration. This is a one year program for experimental and demonstration projects in Solar Utilization/Economic Development and Employment (SUEDE). The program is intended to "demonstrate the feasibility of improving the quality of life in low-income communities by means of: providing solar related training to CETA enrollees; expanding employment opportunities; assisting low-income people with energy matters; increasing the utilization of solar technologies and applications in low-income communities; expanding business development, particularly minority business; and increasing economic development in depressed communities." Each pilot project will train CETA enrollees in the "basic skills to design, construct, install and maintain certain types of solar hot water/space heating or related systems appropriate to the needs of low-income homes." The plans are for "15 to 25 CETA trainees at each site to complete training and to enter the construction, construction-related, and solar trades and other appropriate job markets." Practical experience is provided in the projects by the installation of 30 to 75 solar hot water or space heating systems in each project community. State and local governments will act as prime sponsors for DOL funds authorized by CETA to be used for participants' wages and training expenses, with DOE and CSA funding equipment and material costs. All three agencies will be responsible for providing technical assistance and training, monitoring the projects, and disseminating the results [25].

Federal government programs in most energy areas are concerned with educating the adopters or training persons involved in the design, installation, and service of the new technologies. Training of manufacturing and sales personnel has generally been left to private industry.

SECTION 4.0

GENERAL OBJECTIVES AND ISSUES OF SOLAR ENERGY EDUCATION AND TRAINING PROGRAMS

A number of objectives have been defined for the solar energy education and training effort. The broadest objective of these programs is to provide information about the range of available solar energy systems and their general characteristics. Not only does this aid in the overall diffusion of solar knowledge, but it may also contribute to increased acceptance of the solar energy technologies. With regard to employment, the programs seek to reduce the possibility that a shortage of trained and experienced professionals would be a barrier to diffusion of the innovation. As a whole, the programs might also affect general labor market conditions by easing the structural imbalances caused by energy policy changes and opening up bottlenecks in labor supply. Other objectives proposed by various groups are (1) to improve the employment outlook in some skill categories, (2) to increase jobs for certain groups outside the traditional energy labor force (e.g., minorities, women), (3) to aid in reducing the costs of solar technologies, and (4) to increase the reliability of solar devices and systems.

Deciding on the objectives for a particular program or for the solar training and education effort as a whole requires consideration of some basic issues. The most important issue is whether there is a need for more programs and, if so, of what kind. Answering this question requires clear information about how many and what types of programs are now available, the number and type of graduates, and what types of on-the-job training are provided. The other type of information needed is how many and what types of jobs exist and are projected in the solar energy field. If a long-term shortage of trained workers is the reason given for the training effort, what is the possibility of creating a short-term surplus? Can solar energy workers be trained broadly enough to accept other work in plumbing, sheet metal fabrication, etc., until the market expands? This information is needed before relevant and timely training programs can be developed and implemented.

A second major issue is the role of the federal government in developing curricula, supporting education and training programs (i.e., through organization grants or the use of CETA funds), and/or developing the job market through commercialization efforts. To the extent possible, the federal government presently seems to be encouraging private efforts by schools, industry, and the states rather than taking over direct responsibility for the programs. Examples include supporting the development and widespread use of educational and training curricula, using CETA funds to train underemployed and unemployed individuals, and supporting conferences where educators and trainers can discuss their programs. An additional role for the government to consider is voluntary certification of courses or programs to ensure quality control and comparability of the training.

A third issue is whether there are sufficient numbers and types of trained workers for the manufacture of the solar systems. (The economic historian perspective referred to this area as the skills for machine making and for users of the technology within the firm.) A limited number of studies have looked at whether the actual or perceived shortage of trained workers affects the decision to adopt or produce a new technology. Crossman et al. [5] studied the skill levels before and after the adoption of technological changes in plants, and found very little change. They hypothesized, therefore, that shortages of trained workers restricted plant managers in their decision to adopt a new process. An analysis of the Crossman findings by Thomas [6] and a study by Piore [26] did not support the hypothesized shortage problem. Thomas does, however, say that work is needed on the relationship between diffusion of innovations and employment and training issues, the role of the federal government in training, and the evaluation of existing and proposed training programs. Preliminary indications from a survey of solar companies are that basic manufacturing and fabrication skills are not a problem in the solar energy field and need not be the focus of government education and training programs [27].

A fourth issue involves the basic rationale underlying the solar training effort. Should the effort be focused on expanding the capabilities of persons already within the HVAC field, or on training unemployed and underemployed persons as solar workers? The first view is often argued by trade unions, with the justification that solar energy will be part of larger HVAC systems or will require traditional backup systems, and that the unions have a sufficient number of members to handle the increased work load. The other view is supported by those who consider adoption of solar energy technologies as a chance for decentralized, community-oriented power systems, and as the basis of a growing area of employment which might be of more interest than traditional jobs to those with a history of employment problems. The SUEDE pilot program discussed earlier explicitly addresses the training of unemployed individuals as part of community development. Also, two current programs in prisons are training inmates to produce and install solar collectors (Florida and Connecticut).

A last issue is the optimal allocation of training effort between training workers and training trainers. Neither one can be done alone, and they contribute differently to the diffusion of solar energy technologies. In cases where the U.S. is training solar workers in other countries or in economically depressed areas of the U.S., training the trainers would seem to be the best use of limited human and budgetary resources. The training of trainers may also be a way in which the federal government can influence the content of education and training programs for solar workers and promote the rapid diffusion of new solar energy information and products.

SECTION 5.0

TYPES OF SOLAR ENERGY EDUCATION AND TRAINING PROGRAMS

Education and training programs in the solar energy area take a variety of forms and affect the entire diffusion chain or TDS, from the research and development personnel to the purchaser or user of the innovation. Four broad categories of programs can be identified: general education, professional education, technician training, and infrastructure training. There are no clear lines among these categories, since many of the education and training programs are being designed and marketed for a wide range of audiences (e.g., homeowners, installers, architects, sales persons, engineers). The programs are discussed in the category where they seem to be most focused, with cross-references where necessary. Other categorizations (such as by type of program sponsor) may be more useful for particular readers, but are not as relevant to the purposes of this paper.

Extensive listings of educational and training programs can be found in a number of sources.* This paper will try to present some representative examples, but does not intend to provide a comprehensive listing of all solar education activities currently underway.**

*Listings of available and planned programs can be found in Barker, Helen and Bert Mason. A Preliminary Tabulation of Solar Training and Education Programs, Golden, Colorado: SERI/RR-53-109, November 1978, and "Installing Solar: Training Expands to Meet the Need", HUD Solar States, September 1978, U.S. Government Printing Office. Other listings or directories can be obtained from the following organizations: The National Solar Heating and Cooling Information Center, P.O. Box 1607, Rockville, Maryland 20850 (800-523-2929, in Pennsylvania-800-462-4983); The International Solar Energy Society, American Section, c/o Smithsonian Radiation Biology Lab, 12441 Parklawn Drive, Rockville, Maryland 20852; "California Educational Opportunities for Solar Energy and Energy Conservation at Institutions of Higher Education", c/o Congressman George E. Brown, Jr., 36th District of California. The Congressional Solar Coalition with cooperation from the SERI Academic Programs Branch has conducted a survey of courses offered by educational institutions. The first directory, The 1978-79 National Solar Energy Education Directory, will be available from the U.S. Government Printing Office in February 1979. The Solar Energy Education Data Base resulting from the survey is intended to be annually updated. Plans are to also expand its coverage to include courses offered by unions, industry, public interest groups, and state and local governments.

**Most of the information on specific programs discussed in this paper was gathered in early summer of 1978. Persons wishing later data on enrollments, for example, are referred to The 1978-79 National Solar Energy Education Directory (see prior footnote).

5.1 GENERAL EDUCATION PROGRAMS

General education programs in solar energy are of three types. The first type is aimed at promoting basic awareness and overall consumer acceptance. These programs operate through the regular school system (K-12 and colleges), free universities, adult and continuing education, the mass media, and workshops or conferences. The objectives of such programs are to increase awareness of the energy problems, inform persons about the general types of solar systems available (such as the characteristics of passive solar homes), increase knowledge of conservation practices, and provide general information for the purchase of 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 DOE. These include solar energy experiments, information on energy conservation practices, and information on the role and importance of energy in our 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 information plus information about the technical characteristics of various solar energy systems, the costs and benefits of the systems, and the effects of various policy options on solar energy development. The form of these programs is usually conference sessions or workshops.

A third type of general education effort is the development of instructions, pamphlets, and books for do-it-yourself solar energy systems. Essentially, this provides a short training course in assembly, installation, and repair for the person with general technical abilities. This body of "self-trained, one-time" solar builders is ignored in many training analyses, but may be important in terms of the number of installations.

Courses which combine aspects of these last two types of general solar education are offered at the Weston Center for Open Education, located at the Cambridge School in Weston, Massachusetts. Several non-credit courses are

*Although information dissemination is closely linked to the general education functions, we will not specifically address it in this paper. A useful presentation of information dissemination issues and an evaluation of DOE programs in that area are presented in A Critical Review of Ongoing and Planned Government-Supported Solar Energy Technology Transfer Programs, Vol. 1-Report, MITRE/METREK, December 1977, M77-121, DOE/4041-77/1.

**DOE energy education publications are available free of charge from the U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830 offered for anyone interested in solar energy--e.g., homeowners, architects, builders, and trades technicians. Seven courses, most consisting of seven two-hour sessions, are taught by two professional engineers with new classes beginning every eight weeks. Enrollment averages about twelve students per course; between 400 and 500 people have taken the solar courses at the Weston Center since the program's inception four years ago [28]. Three of the courses are involved with theoretical aspects of solar systems: "Basics of Solar Heating," "Introduction to Solar Heating," and "Advanced Studies in Solar Heating." Two other courses concentrate on design aspects, "Solar Heating System Design I & II," and "Designing Your Own Solar System." The last course is entitled, "Social Aspects of Solar Heating."

Another private institution with a somewhat different approach is Cornerstones, or the Wing School of Shelter Technology, in Brunswick, Maine. A school for owner-builders, Cornerstones offers two three-week courses, "New House Construction" and "Retrofitting Existing Houses." Both courses emphasize the inclusion or addition of energy-conservation measures and passive solar systems in homes considering variables such as site and climate information, insolation, and availability of various mechanical systems. No previous experience in home design or construction is required to enroll. After completing either "basic" course, those planning to build homes in the future can enroll in the Design Workshop, or in a fourth course which provides hands-on carpentry experience. Each of these advanced courses also emphasizes passive solar systems. Enrollment has numbered as high as 40 students per course, with a total of approximately 500 to date [29].

5.2 PROFESSIONAL SOLAR ENERGY EDUCATION AND TRAINING

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, workshops, conferences, and short-courses offered by industry or union groups. The programs teach the principles of solar energy systems and the problem defining and solving skills needed by solar energy professionals. The types of people involved include research and development personnel, architects, urban planners, system designers, and engineers. These persons need some degree of technical expertise in solar energy technology, but also need a broad educational base to be professionally accepted.

5.2.1 <u>Degree Programs</u>

A bachelor of science degree program has been developed at Colorado Technical College in Colorado Springs (B.S. in Solar Engineering Technology). The first two years of the program are solar technician training leading to an Associate Degree in Applied Science, while the last two years focus on mechanical engineering technology [30].

The suggested sequence of study combines courses in physics, mathematics, business, and applied science, including topics such as solar system design, heat transfer, thermodynamic fluid mechanics, and heating, ventilation and cooling (HVAC) design. Although the mechanical engineering technology of HVAC systems is emphasized, the program is "rounded out" with courses such as report writing, statistics, personnel management, business law, and U.S. history.

The two-year associate degree program is intended to prepare enrollees for employment as "solar technicians," while the four-year bachelor's degree provides students with the background required for work in "solar engineering technology." About 100 students are currently enrolled in both programs, which are in their fourth year of instruction [31].

Also in Colorado, a bachelor's degree in Energy Science is among the programs offered by the University of Colorado in Colorado Springs. This program combines courses in several disciplines: engineering, physics, chemistry, mathematics, economics, geology, and various elective topics. In fulfillment of the degree's requirements, students may take the courses, "Solar Energy I and II," which attract average yearly enrollments of about 150 and 60 students, respectively [32]. The first is a lower division, "nuts and bolts"-type course, where different examples of solar collectors are constructed and analyzed. The upper division course is more theoretical, covering aspects of heat transfer and storage systems, among others. In addition, about 25-30 students--primarily from the upper division--are employed for 10-20 hours each week at the Education and Research Facility for Energy Science (ERFES), a solar energy research installation near the campus. The facility operates several research experiments, including eight water collectors, eight concentrating tracking collectors, fifteen air collectors, a solar greenhouse and machine shop, and weather-monitoring equipment, with plans to construct a passive solar testing facility sometime during the next year [33].

Thirty-six universities offer graduate programs or curricula in solar energy areas. The solar graduate program at Arizona State University requires one year of course work plus a thesis. The degree is a Master of Environmental Planning within the College of Architecture, and may have a concentration in solar architecture or solar technology. The University of Texas at Dallas offers a Ph.D. and an M.S. in Environmental Sciences with a specialization in solar energy. The solar curriculum is composed of six solar energy or general energy courses. Students are trained for positions as researchers or solar engineers. The College of Engineering at Oklahoma State University in Stillwater offers a program in electrical engineering with an emphasis in energy. Ten courses are offered in energy systems, solar energy, and alternative energy systems. Students may receive a Ph.D, M.S., or B.S. with the energy emphasis.

5.2.2 Solar Energy Courses

A number of other schools have developed individual courses on solar energy systems and technologies for their students. For example, the Solar Energy Applications Laboratory at Colorado State University in Fort Collins has developed two courses in solar heating and cooling of residential buildings, titled "Design of Systems" and "Sizing", Installation, and Operation of Systems". Primarily intended for professionals and tradesmen in the home building industry, the courses may ultimately be implemented nationwide to equip practitioners with the fundamental skills necessary to design, install, and maintain residential solar systems.

The CSU courses were prepared after an assessment of standards and needs was developed in association with architects, engineers, HVAC trademen, and builders. The courses were developed by the Solar Energy Applications Laboratory, CSU vocational education specialists, and the National Association of Home Builders (NAHB) Research Foundation, Inc., of Rockville, Maryland. In addition, guidance in the orientation and content of the courses was provided by a national advisory council, whose members included engineers, architects, educators, home-building practitioners, and government representatives.

Each course's modularized structure allows for latitude in the order and length of presentation, providing enough flexibility to offer either short, concentrated classes or extended evening sessions. At Colorado State, for example, the design course is taught in five continuous days.

At the University of New Mexico in Albuquerque, two three-credit courses are offered by the Department of Mechanical Engineering, titled "Application of Solar Energy to Engineering Systems," and "Solar Energy System Design/Analysis." The first course involves an "engineering analysis of applications of solar energy," including their integration into existing conventional energy systems. The second course analyzes "dynamic thermal systems and use of the results for design of engineering systems, including those using solar energy" (course descriptions). Also, students may further their studies of solar applications in the courses "Undergraduate Problem" and "Graduate Problem."

Two three-credit courses are conducted by the College of Engineering and Technology at Northern Arizona University in Flagstaff: "Solar Energy Technology" and "Solar Engineering Analysis and Design," both for engineering students. In the first course, basic concepts of heat transfer, solar collectors and energy storage systems are reviewed, including examples of electric power generation, "high-technology" houses, and solar heated buildings. An elementary project in solar system design is also required. The second upper level course is somewhat more theoretical, covering topics such as absorption refrigeration and cooling, heating and cooling design, and computer applications (including system performance optimization).

In the Southeast, a graduate course entitled "Solar Energy Engineering" is presented to about 30 students each semester by the Department of Mechanical Engineering at Georgia Institute of Technology [34]. To date, approximately 150 graduate students have taken the course, which covers analytical aspects of solar design, modelling of solar processes, performance analyses, and solar system integration/control.

5.2.3 Continuing Education

Continuing education efforts (short courses and workshops) are particularly useful for practicing engineers, builders, and others. For professionals with little or no experience in solar heating and cooling, Georgia Institute of Technology offers a concentrated, three-day program through its Department of Continuing Education, "Solar Heating and Cooling for Homes and Buildings." It is designed to familiarize people with a bachelor's degree in science or engineering (or the equivalent background) in the solar state-of-the-art, emphasizing the technical and economic aspects of various systems.

At the University of Alabama in Huntsville, the School of Continuing Education offers a course in "Solar Heating and Cooling," also requiring a bachelors degree (or equivalent) in engineering or a related area. The course encompasses a survey of current technology in solar space heating and cooling, a review of applications, weather data and economics, and a discussion of performance analysis techniques.

The University of Alabama also offers two evening continuing education courses for engineers: "Solar System Analysis: Part I (Heating System Performances) and Part II (Subsystem Performance)." The first course introduces the principles of performance estimation and economics of solar heating systems, with an overview of collector performance estimation, storage system sizing, and calculation of solar flux. The second course involves a study of solar subsystems, including liquid and air storage systems, heat exchangers, solar-assisted heat pumps, etc., emphasizing subsystem performance calculations.

In Philadelphia, Drexel University's Continuing Professional Education Department offers a noncredit course for practicing engineers and qualified HVAC journeymen, titled "Solar Heating and Cooling." In providing students with a working knowledge of solar fundamentals, applications and techniques, topics covered include a historical overview of solar systems, solar radiation, collector design and performance, system design, economic analysis, and a design workshop that analyzes enrollee's proposed applications. Computer programming is used to analyze system cost and performance, which limits the class size to about 25-30. As of summer 1978, about 150 people had participated in Drexel's program.

"Solar Energy Thermal Processes" is a five-day short course offered at the University of Wisconsin in Madison. The course is intended to provide engineers and architects with a working knowledge of thermal processes in solar energy utilization, assuming previous experience in the area of heat transfer and thermodynamics. Through a combination of lectures and problem-solving tutorial sessions, participants cover aspects of solar radiation, collector design and performance, storage units and components, methods of process system analysis, applications to thermal energy requirements of buildings, industrial processes, and the cost of solar processes. Computer programs for predicting thermal performance and life-cycle economic assessments are used.

At the University of Connecticut in Storrs, a three-credit graduate course for engineering students and professionals is offered one evening per week. Topics of study include the technology and economics of solar energy conversion, collector design and performance analysis, heat transfer and energy storage, and design of solar water heating-space heating-cooling systems. Although the course is presented at the main (Storrs) campus, classes are also broadcast via television to five branch campuses equipped with a special talk-back system.

Other solar courses in Connecticut are available through the Hartford Graduate Center's Environmental Science and Technology Program, paralleling its Master's Degree in Environmental Science. Three noncredit courses are available on either a semester or short-course basis for professional engineers, architects, builders, and HVAC tradesmen, titled "Solar Energy for Buildings," "Advanced Solar Energy System Design," and "Solar Energy System Selection, Installation, and Maintenance." The first course entails the evaluation of existing structures, proposes solar systems, and then determines economic feasibility. The second course involves designing a working system from component parts, while the third provides an overview of installation and maintenance requirements for various systems. About 500 people have enrolled in all three courses, which have been offered for about two and one-half years [35].

Among the many summer conferences presented in 1978 by the College of Engineering at the University of Michigan, two were designed for engineers, architects, urban planners, contractors, energy consultants, and others interested in energy management and utilization. Titled "Solar Energy for Heating and Cooling--Commercial and Residential," and "Solar Energy Measurement and Instrumentation," both short-courses were comprised of five days' lectures, informal discussions, workshops, and laboratory sessions. A degree (or the equivalent experience) in engineering, science, or architecture was desired, but not necessary to participate.

The first short-course emphasized the engineering and architectural aspects of solar heating and cooling systems, but included discussion of other solar applications as well. Lectures were presented on topics including engineering systems, economics, and system design considerations, both for new and existing structures. The solar measurement and instrumentation course provided a familiarization with the physical principles of solar and infrared radiation, specified measurement techniques, and data evaluation.

Three other short courses are available from the Center for Management and Technical Programs, Division of Continuing Education, at the University of Colorado in Boulder. "The Practical Design and Economics of Solar Heating and Cooling Systems" is a three-day seminar offered several times a year, for architects, contractors, and planners interested in the basic principles and applications of solar systems. Course topics include fundamentals of solar radiation and heat transfer, methods of solar energy collection and utilization, and solar heating-cooling-air conditioning of buildings. With an emphasis on practical applications, students learn how to size system components, design control operations, architecturally integrate solar collectors, perform economic analysis, and summarize maintenance requirements [36].

Another seminar held at the University of Colorado is titled "Industrial and Commercial Applications of Solar Energy." This course, which requires a degree in science or engineering (or experience), emphasizes nonresidential process heat applications and addresses various aspects of concentrating collectors, thermal systems components, conversion systems configurations, performance predictions, economic analysis, and performance optimization. After completing the course, students are able to determine the feasibility of alternative processes in various applications, evaluate system economics on a life-cycle basis, and carry out a solar system's schematic design [36].

Finally, a three-day advanced course is available, also at the University of Colorado, which requires a degree in science or engineering, solar engineering experience, or a previous course in solar design. Titled "The Technical Design of Solar Thermal Systems for Buildings," the seminar makes use of computer aided design methods and modeling, via an illustrative design problem supervised by the faculty. Other topics are: principles of heat transfer and optics, flat plate and advanced collector performance, systems analysis, and economic considerations.

In the Pacific Northwest area, the Northwest Solar Institute of Long Beach, Washington, offers three-day seminars on basic solar energy topics. Emphasizing the basic concepts of solar systems and their practical application, the sessions consist of lectures on solar heating and cooling/domestic hot water system, design factors, architectural implications, site planning, heat loss, solar collector heat gain calculations, and various types of storage systems. The seminar is designed for an audience of architects, engineers, contractors, and designers, as well as homeowners, and is currently offered once a month.

5.2.4 DOE Workshops

DOE has sponsored or participated in several workshops for practicing engineers, contractors, etc., three examples of which were held during the winter of 1978. One of these consisted of a series of seven one-day workshops held at universities in the North Central states from January to May, entitled "Design for the Sun." Prepared by the Solar Store of Peoria, Illinois and supported by DOE funds, the conference toured the different universities to brief an audience of architects, engineers, contractors, and HVAC tradesmen in aspects of solar technology and design. Accompanying the workshop was an exhibit of award-winning solar home designs, the product of a competition held in 1977 by the Illinois Committee on Energy and Architecture. The consortium of universities that was established also led to a greater degree of cooperation in developing solar curricula for architecture, engineering, and design students.

Each university developed its own program, although the other universities provided input, and a core of three speakers attended each session. In total, nearly 2,400 individuals participated in the series. The success of these conferences encouraged the development of another set of conferences focusing on passive solar energy, tentatively to be offered in the fall of 1978 [37].

During February and March, 1978, DOE conducted four two-day introductory workshops on solar heating and cooling installation in the Northeast. The course was presented by engineers from the Honeywell Energy Resources Center, using materials developed by the Solar Energy Applications Laboratory at Colorado State University. Designed for architects, engineers, HVAC contractors and builders, the sessions provided instruction on topics such as collector systems, design and sizing methodology, economics of solar systems, and passive design. In addition, the Transportable Solar Laboratory toured with the workshop, exhibiting collectors, components, and other solar equipment currently available.

The third example of DOE-affiliated workshops was held in San Francisco, February 15-19, 1978. Titled "The Use of Solar Energy for the Cooling of Buildings," this seminar was primarily intended for researchers, government and public utility representatives, product development engineers and manufacturers, as well as other interested individuals. The lead DOE agency for the seminar was the Conservation and Solar Applications Research and Development Branch, which provided the forum for discussion of the present status, problems, and future of solar-cooled buildings.

5.2.5 Industry Programs

Industry groups have also been involved in the development of educational materials and courses for training professionals in solar heating and cooling. As an example, in 1974, Bell & 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. In addition, as a by-product of the data obtained from its research, Bell & Gossett ITT has prepared and published its "Solar Heating System Design Manual" for engineers, architects, builders, and students. This technical publication covers types of solar systems and flat-plate collectors, design examples, building heat-loss calculations, and a description of the Bell & Gossett ITT hydronic solar heating/cooling system.

Another, more specialized application and installation manual has been compiled by the Fedders Corporation of Edison, New Jersey, for its Split System Heat Pump and Solarflex Collector System. This manual was prepared for Fedders contractors and builders, and provides them with recommended minimum operating requirements for the solar-assisted heat pump, including methods of calculating heating requirements and installing collector panels.

Fedders also prepared a "Bill of Materials and Preliminary Cost Estimator" for its Solarflex system, to aid its dealers and contractors in selecting and pricing component materials required for installation. The bill includes a ten-page item-by-item list of those components and estimated person-hours required to determine the total cost of a solar-assisted heat pump system.

Among the companies specializing in solar heating and cooling systems, Solaron Corporation of Denver, Colorado, has published a design manual intended for architects and mechanical engineers. Included in the manual are a general description of the Solaron system, component and system performance data, sizing and design considerations, and a discussion of operating and maintenance requirements. Figures and tables provide additional information on collector performance, sizing curves, solar radiation, etc., including several worksheets to aid calculations.

Solaron also conducts bimonthly training seminars for architects, engineers, and Solaron distributors and dealers, with an average attendance of about 30 [38]. The three-day session provides instruction in systems applications, installation and start-up procedures, sizing, organization and design, selling techniques, and solar collector/system theory, supplemented with field trips to Solaron installations [39].

Another education seminar which has been held for nearly five years is offered by Thomason Solar Homes of Fort Washington, Maryland--inventor of the "Solaris" system. Nearly 400 people from various backgrounds and interests have participated in the two-day sessions, scheduled every four weeks. The course provides basic instruction in the design and installation of "Solaris" systems through the use of filmstrips, transparencies, field trips, and question-and-answer periods. The seminar furnishes a background for those interested in applying for the two-year Solaris license. At present, there are about 24 licenses nationwide, each of whom is required to pay a royalty to Thomason Solar Homes [40].

5.3 TECHNICIAN TRAINING

Educational institutions, unions, industry groups, and state organizations have developed and offered technician training programs. Persons participating in the program may have just a high school degree or may be experienced HVAC workers. The courses generally focus on sizing, installation, and servicing of residential and commercial energy systems, rather than on manufacturing skills.*

5.3.1 Degree Programs and Courses

A number of educational institutions offer pr[illegible] leading to associate degrees in solar technology. One of the most comprehensive programs currently available is that offered by Colorado Technical College of Colorado Springs, in Solar Engineering Technology. The private, four-year school offers an Associate in Applied Science and the Bachelor of Science (previously discussed in section 5.2.1). The two-year associate degree program is intended to prepare enrollees for employment as "solar technicians".

Another institution offeri[illegible] an associate degree in solar technology is San Jose City College in San Jo[illegible], California. This program is designed to equip HVAC students with solar skills. Instruction is provided in air conditioning and refrigeration theory, design, installation, and maintenance of solar systems. In addition to physics, mathematics, and computer theory, elective courses may also be taken in history, government, English, speech, and ethnic studies. Two strictly solar classes, focusing on residential and industrial applications, had a total enrollment of nearly 70 students during the 1977-1978 academic year, with eight other students attending a solar special projects course [41].

San Jose's Associate Degree requires 64 units of credit over four semesters. For those desiring a less comprehensive program, the college also offers a one-year certificate of achievement degree requiring only 30 units of credit. Students can thus receive the basic instruction in air conditioning and refrigeration principles, hydronics, and solar applications without taking the mathematics, physics, or elective courses required for the two-year degree.

The Community College of Denver also offers an associate degree program in Solar Energy Installation and Maintenance at its Red Rocks Campus in Golden, Colorado. Emphasizing hands-on practical applications, the program is designed to prepare students for employment in solar system installation and maintenance and to enlarge the background of those already employed in the field.

Required courses include solar system design and panel construction, testing and evaluation, collector installation, maintenance, controls, passive solar systems, and introductory photovoltaic and wind energy applications. To supplement these solar courses, students also receive instruction in basic plumbing and water piping methods, bricklaying, blueprint reading, and carpentry for construction trades, and basic sheet metal techniques. Fifteen

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*For a discussion of jobs involved in the installation of solar energy systems, see Solar Energy Task Force Report: Technical Training Guidelines. October 1978. To be presented at the DOE National Energy Education, Business, and Labor Conference, January 15-17, 1979, Washington, D.C.

of the required 78 hours consist of math, English, or social science electives. Over 150 people are presently enrolled in the course, including engineers, architects, tradesmen, builders, and homeowners (homeowner builders). Thus far, about 100 people have completed the nine-month program [41].

Four schools are presently involved in a joint project to develop an associate degree curriculum for solar technician training (Navarro College in Corsicana, Texas; Cerro Cosa Community College in Ridgecrest, California; Northlake College in Irving, Texas; and Brevard Community College in Cocoa, Florida). The project is being funded by grants from ERDA (now part of the Department of Energy) and the Texas Education Agency, with the development of materials for labs and sections based on a solar task analysis which was previously completed by Navarro College under contract to DOE.

Utilizing a prototype-version of the curriculum, Navarro College expects to offer a one-year certificate degree program in solar installation during the 1978-1979 academic year, for an audience with little or no experience in conventional heating systems [42]. The two-year associate degree curriculum will probably be offered in the fall of 1979. It is designed to train "solar engineering technicians and paraprofessionals". The curriculum is intended to serve as a foundation for other community colleges wishing to implement a similar program.

Mohawk Valley Community College in Utica, New York, is offering a course in basic solar installation-maintenance-repair as an adjunct to its heating and an air conditioning program. Scott Community College in Bettendorf, Iowa, has developed an eight-quarter curriculum titled "Solar Energetics Technology." The basic HVAC program is extended to encompass applications in solar energy, training students in solar design, installation, and maintenance. There are about 26 students in the present class (September,1978) [43].

Finally, a three-credit technical elective in Solar Energy Architecture is offered in fulfillment of requirements for an associate degree in Architectural Technology at William Rainey Harper College, located in Palatine, Illinois. This is a fundamental course that surveys the various low temperature applications of solar energy by examining principles of solar radiation, climatic data, heat loss calculations, various collector systems, solar costs, and design problems.

5.3.2 CETA Programs

Several CETA-funded solar technician training programs have already been implemented, principally in California. One of the earlier experiments was conducted during the summer of 1976 at the San Jose Branch of the Center for Employment Training, which offered a course in building maintenance for 37 former migrant farm-workers. A grant of $42,000 from the California Energy Resources and Development Commission and the State Governor's CETA discretionary fund enabled the trainees to apply their skills, fabricating and installing solar hot water systems in 30 housing units and four other buildings [44]. The panels made were simple and inexpensive, but after completing the course students were eligible for jobs as solar mechanics, with training in solar system installation, maintenance, and repair.

Another CETA-funded program is offered by California State University at Sonoma (formerly Sonoma State College) which has conducted its Solar Technician Training program since 1976. The curriculum combines classroom and hands-on training in solar technology and business management. The program has been asked by the California Office of Appropriate Technology to provide educational guidance for solar training programs throughout the state [45]. Aimed at the unemployed and underemployed population of Sonoma County, the program's enrollment is limited to 16 students per session, selected from over 150 applicants. Of the 32 students who have completed the course to date, 30 are reportedly employed in the solar energy field [46].

Over two semesters, students receive instruction in solar design, collector sizing and installation, and economic feasibility computations. Other courses in physics, small business management, algebra, and trigonometry are also required. On-the-job training for the 1976-1977 class entailed the incorporation of active and passive heating systems into a 500 square foot alternate energy center located on the Sonoma campus, where three student-designed-built-installed collector panels are continuously monitored. Following a comprehensive final examination at the completion of the course, a certificate degree is awarded to each graduate, who is then qualified for employment as an installer, salesperson, consultant, or a variety of other solar-related positions. In some cases, CETA funds are available to defray the initial cost of employment.

Also in California, the Office of Appropriate Technology (OAT) and the Office of the State Architect (OSA) offered its Solar Technician Program in two 22-week sessions from November 1976 to October 1977. Funded primarily through the Sacramento-Yolo County CETA Office, the course was limited to 18 unemployed and underemployed men and women from the area [47].

During the first 10 weeks of the course, participants received classroom instruction in solar theory, system design, and economics, in addition to basic training in plumbing, electrical, and carpentry skills. The next 12 weeks provided hands-on experience in the design and construction of seven retrofitted systems, including solar hot water installations on a state office building and Governor Brown's apartment.

According to one of the training supervisors, the pilot program's trainee could be categorized somewhere between solar mechanics and technicians, as determined by the quantity of theoretical knowledge that they possessed. It was concluded from the program experience that 22 weeks to train a solar technician was insufficient, recommending 10-14 months of concentrated instruction or a two-year junior college curriculum instead [47]. OAT is currently developing a comprehensive training curriculum for solar mechanics, technicians, and engineers, to be supervised by OAT and implemented by

California community colleges wherever the demand arises. Intended for unemployed and underemployed individuals, the solar mechanic curriculum will probably be a two-semester program leading to certification in solar system installation and maintenance. The solar technician program will probably require an additional year's training at a community college, to equip students with skills in system sizing and design. With further training, those qualified in troubleshooting would be categorized as "solar engineers" [48].

5.3.3 Union and Industry Programs

For those unable to participate in other training programs, an accredited correspondence course--"Fundamentals of Solar Heating"--is currently providing mail-order 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, and funded by a grant from DOE's Solar Technology Transfer Program [49]. Based on materials provided by the Solar Energy Applications Lab at Colorado State University and publications 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.

The structured course consists of eleven lessons over a period of 10-12 weeks, with topics including: an overview of solar heating and cooling systems, solar radiation, collectors, heat storage, controls and accessories, sizing of components, operation of systems, domestic water heating, installation, servicing, and legal responsibilities. A working knowledge of heating and cooling fundamentals, duct and pipe sizing, and basic conventional system design is assumed.

To broaden the impact of the course and increase the completion rate, DOE initiated an "outreach homework assistance plan" to be administered by five national laboratories: Lawrence Livermore Laboratory, Livermore, California; Oak Ridge National Laboratory, Oak Ridge, Tennessee; Brookhaven National Laboratory, Upton, New York; Sandia Laboratories, Albuquerque, New Mexico; and Battelle Pacific National Laboratory, Richland, Washington [50].

The completion of a second SMACNA course, the Better Heating and Cooling Program, qualifies contractors to offer a three-year solar system performance warranty, underwritten by the participating contractors [51].

Another example of private-sector activity in technician training is the 4 week, 160 hour Solar Heating Installation and Maintenance course conducted by the New England Fuel Institute of Watertown, Massachusetts. Emphasizing practical applications, this program assumes no previous technical or solar experience, although enrollees should be high school graduates or licensed in a trade (plumbing, HVAC, etc.). The course is intended to provide the basic theory and applied training required to install and service solar systems. Approximately 100 of the 160 hours in the program are devoted to practical laboratory instruction, with the remainder of the time spent in a classroom. Special emphasis is placed on the integration of solar equipment into new and existing oil heating systems [52].

The course reviews various technical and mechanical aspects of solar installation and maintenance, including basic concepts, installation techniques, system testing, troubleshooting and servicing, business and financial considerations, and current industry developments. The discussion of different types of solar systems, of both the air and water-type is oriented toward equipment of the leading solar system manufacturers. The program has been supplemented by field experience gained through the installation of over 100 solar installations throughout New England, made cooperatively by the Institute and qualified-member oil heating firms or NEFI-member companies.

The class is offered six times a year. Enrollment is limited to 15 students (usually averaging about ten) most of whom are from Massachusetts and other Northeast states, with some from states as distant as Louisiana and Arizona [53].

5.4 SOLAR INDUSTRIES INFRASTRUCTURE TRAINING

Training programs for persons in the solar industries infrastructure combine aspects of a general education program and a limited technical program. These persons include sales, marketing and service managers in the solar industry; utility company planners and managers; distributors and dealers; real estate developers and agents; and members of financial institutions. Persons in this category play particular roles in the technology delivery system for solar technologies.

This area has received much less attention than the other education and training categories. These persons can participate in many of the short-courses, workshops, and associate degree programs, although much of the technical content may not meet their needs. They may participate in solar training programs developed by solar energy firms. Or, they may be expected to acquire their solar knowledge on the job. Discussions are needed with industry representatives to determine the training options and the company characteristics influencing the type of training used.

Two programs which were discussed earlier with the professional courses specifically include distributors, dealers, and sales personnel. These are the Solaron bimonthly training sessions and the "Solaris" system seminar for those wanting a distributors license. In addition, the two Fedders Corporation manuals discussed earlier are directed at dealers, sales personnel, contractors and builders. A number of the CETA technician training programs in California also train individuals in sales and consulting jobs.

SECTION 6.0

CONCLUSIONS

This paper is meant to provide a basis for analysis of the labor force supply questions in the solar energy field by (1) identifying the role of education and training in the diffusion of new technologies such as solar energy systems, and (2) defining issues important to developing and evaluating education and training policies and programs.

Four perspectives on diffusion research were reviewed in order to build on the knowledge gained from existing studies of the diffusion of technological innovations. The adoption and development perspectives were shown to be relevant to developing general education programs aimed at potential adopters of solar energy systems and to identifying possible causes of resistance. The market and infrastructure perspective and the economic history perspective address the institutional mechanisms for and barriers to diffusion of a technological innovation. As such, they implicitly include the education and training of people involved in the production and delivery of the innovation. In addition, the economic history perspective explicitly considers the skills of the users and the skill in machine making. These two perspectives and the current attempts to define the solar energy technology delivery system (TDS) illustrate the importance of education and training in diffusing a technology and identify the various types of persons to be reached by the education and training programs (e.g., installers, building tradesmen, real estate developers, loan officers, utility company planners).

Five basic issues are raised and discussed in Section 4.0. The first issue is whether there is a need for more programs and, if so, of what kind. The examples cited in Section 5.0 illustrate the large number and variety of courses and programs offered by public and private institutions. These existing efforts provide a rich source of experience for modifying and developing curricula and programs and for evaluating what does and does not "work" in solar energy training. Such evaluations have not yet been done, but are being facilitated by the information bases being developed by SERI, the National Solar Heating and Cooling Information Center, the Solar Energy Industries Association, and the International Solar Energy Society.

In most cases, education for solar careers is handled by adding one or more courses to an existing curriculum or providing short-courses and seminars for practicing professionals. Special curricula or undergraduate or graduate programs in solar energy are less frequent (an example is the Colorado Technical College's B.S. in solar engineering technology). Technical training in solar energy ranges from single courses added to vocational and trade school or community college curricula to associate degrees (an example of the latter is offered at San Jose City College). There have been no broad evaluations to date of the quality of courses and programs, or of the mix of programs. Nor has there been sufficient evaluation of the extent of solar training needed for professionals or technicians. The question of whether there are "enough" education and training programs to meet the possible long-term demand cannot be answered with the data available for this paper. Ongoing efforts by SERI to assess the employment requirements of solar energy (Analysis and Assessment Division) and to determine the complete inventory of solar education and training programs and their yearly output of students (Academic Programs Branch) will enable a better assessment of the adequacy of the present programs. The inventory of current programs should also contribute to answering whether we are producing a short-term surplus of solar workers or whether the individuals are being trained broadly enough to handle traditional HVAC or construction jobs until solar jobs materialize.

The information available to date indicates that the solar education and training efforts are reaching a wide variety of people in a number of geographical areas. Participants in solar courses and programs come from a number of groups in society, including CETA eligibles, professional engineers, elementary school students, and homeowners. The geographical dispersion indicates that groups in all parts of the country are interested in solar energy. Persons in a wide spectrum of occupational groups are taking solar energy seriously enough to learn more about it through a course, workshop, or seminar.

An analysis is not yet possible of whether present efforts in the four categories of solar education and training programs are balanced with each other and responsive to overall solar commercialization strategies. A SERI pilot study of state-sponsored programs found an imbalance in the number and type of programs, with the residential user oriented programs outweighing the technical training programs [55]. This paper does not add to the analysis since only illustrative examples were included. Again, the SERI data bases will allow analyses of this type in the future.

The second issue is the role of the federal government in supporting the education and training effort in the solar energy field. Given the range and number of existing programs, it does not appear that government encouragement is necessary for the development of courses and programs. There are a number of ways in which the federal government could play an important role, however. One of these is to continue to support the development of curricula and educational materials in order to disseminate information and technologies developed in federal research projects. A second is to provide overall analyses of the problems facing solar programs, especially availability and costs of materials and trained staff and to develop measures to reduce these problems. A third is to integrate the student count of the programs with the long-term employment projections in order to anticipate labor shortages and surpluses. A fourth is develop mechanisms to encourage or ensure quality standards for solar energy training programs and for solar installation practices. The New England experience pointed out the importance of having standards for solar training and solar installation. Installation problems are a concern to both manufacturers and purchasers of solar energy systems. The quality of training is also an important concern in deciding how solar energy technology warranties are going to be handled.

The third issue is whether there are sufficient numbers and types of trained workers for the manufacture of the solar energy systems. As indicated earlier, the federal government has in most cases left those programs to industry. A preliminary survey of solar energy companies [27] has not found the availability or training of basic manufacturing and fabrication skills to be a problem as yet.

The fourth issue concerns the tradeoffs between expanding the capabilities of persons already within the HVAC field and training unemployed and underemployed persons as solar workers. Courses have been developed for union workers in sheet metal and HVAC trades, and also for CETA eligibles. No evaluation has been done of the importance of experience with conventional systems, of the role of unions in regulating the quality of installation, or of whether CETA trainees working in installation areas become affiliated with unions.

The fifth issue raised is the allocation of effort between training workers and training instructors. It is not clear from the information presently available how many of the participants in the various courses or programs become, in turn, solar instructors. Analyses in this area would have to consider the variety of teaching experiences such as union apprenticeships and community seminars as well as academic courses. It is hoped that national surveys such as the SERI Solar Energy Education Data Base can identify programs specifically aimed at training instructors and can also determine whether there is presently a shortage of qualified solar energy instructors.

This paper has tried to identify the importance of educational and training programs in the diffusion of solar technologies, illustrate the types of current efforts, and define policy issues of concern to program designers and managers. It is hoped that the training and manpower studies of SERI's Analysis and Assessment Division will provide information useful in evaluating these ongoing efforts and addressing the broad policy issues.

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APPENDIX A
COLLEGE AND UNIVERSITY
COURSE AND PROGRAM DESCRIPTIONS

This listing reflects only those materials and programs referenced in this paper, and is by no means a complete listing of the courses and programs available. Information on additional courses and programs can be found in the SERI Solar Energy Education Data Base.

(organized by state)

Alabama

School of Continuing Education, "Solar Heating and Cooling," Solar System Analysis: Part I Acting System Performances," and "Solar System Analysis: Part II Subsystem Performance," Huntsville, Alabama: University of Alabama, course descriptions.

Arizona

College of Engineering and technology, "TEC 210-Solar Energy Technology" and "EGR 451-Solar Engineering Analysis and Design," Flagstaff, Arizona: Northern Arizona University, course outlines, conversation with Dr. B. W. Davis, July 25, 1978.

California

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Colorado

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Connecticut

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Georgia

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Maine

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Massachusetts

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Michigan

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New Mexico

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Pennsylvania

Colleges of Engineering and Science, "Solar Heating and Cooling", Philadelphia, Pennsylvania: Drexel University, course description.

Washington

"Continuing Seminars on Solar Energy", Long Beach, Washington: Solar Northwest Institute (course description).

Wisconsin

Department of Engineering, "Solar Energy Thermal Process", Madison, Wisconsin: University of Wisconsin-Extension, course description.

APPENDIX B
INDUSTRY AND LABOR COURSE DESCRIPTIONS

This listing reflects only those materials and programs referenced in this paper, and is by no means a complete listing of the courses and programs available. Information on additional courses and programs can be found in the SERI Solar Energy Education Data Base.

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