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ABSTRACT

A Navarro College, Texas, study determined the quantitative and qualitative needs for developing skilled manpower for the solar industry and secondarily identified the (present) solar industry manpower populations and tasks performed by solar technical and skilled workers. Results from three initial working groups addressing equipment, market penetration, and skills analysis were combined by a fourth manpower assessment group to (1) forecast solar-trained manpower needs and (2) determine the training required to produce manpower capable of performing the identified tasks. Based on data from available market studies, the demand for trained workers to design, install, and maintain solar systems will be substantial and will develop concurrently with the demand for solar equipment. According to solar market projections, 2.4 million solar units will be installed by 1985. By that time there must be 25,000 skilled workers in the solar field, one-fifth trained at the technician level. Solar technician training should be equivalent in length and extent to that for heating, ventilating, and air conditioning technicians--approximately a two-year program. Solar mechanics training can continue to be provided by solar industry. To meet the demand, approximately eight schools, each graduating fifty solar technicians a year, are needed. (Tables and figures are appended.) (YLB)

AN ASSESSMENT OF NEED FOR DEVELOPING AND IMPLEMENTING TECHNICAL AND SKILLED WORKER TRAINING FOR THE SOLAR ENERGY INDUSTRY

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ABSTRACT

In order for the solar industry to be successful in stimulating commercial use of solar energy, it must provide for the development of manpower resources with the knowledge and skills to install and maintain solar systems. The significance of the demand for solar equipment and solar workers must be known before plans can be made to develop a curriculum to train these workers. The first objective of this paper is to present the national need for manpower trained in solar energy technology and report it by state. The second objective is to identify the solar industry manpower populations and to identify the tasks that should be performed by solar technical and skilled workers. An analysis of this information will provide the manpower population determination and should aid in solar manpower curriculum design.

DESCRIPTION OF THE PROJECT

In order for the solar industry to be successful in stimulating commercial use of solar energy, it must provide for the development of manpower resources with the knowledge and skills to install and maintain solar systems. The significance of the demand for solar equipment and solar workers must be known before plans can be made to develop a curriculum to train these workers. There should be a well founded expectation that there will exist a clear demand for the training, and employment opportunities for the graduates of the training program. Heretofore, there have been insufficient data available regarding the number of solar energy workers that could be employed in this new and emerging field. This paper reports the findings of a study performed by Navarro College for the Department of Energy to determine the quantitative and qualitative questions for manpower in the solar energy industry. The objective of this project has been to determine the national need in the United States for manpower trained in solar energy technology and report it by state. This project forecasts future manpower requirements for the solar industry by determining both the quantitative and qualitative needs for developing solar skilled manpower.

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Secondary objectives have included the identification of the solar industry manpower populations and the identification of tasks that should be performed by solar technical and skilled workers. An analysis of this information has provided the manpower population determination and should aid in solar manpower curriculum design.

The project contract had three basic tasks:

Task 1. Conduct a survey of solar heating and cooling systems equipment using ERDA, NASA, and private industry resources.

Task 2. Review existing consumer demand studies to forecast manpower requirements.

Task 3. Conduct a skills study to determine the types of curriculum required to produce the trained manpower identified in Task 2 above.

The final solar manpower assessment was formulated from the results of these three tasks.

Three separate working groups were formed to address these tasks: an equipment group, a market penetration group, and a skills analysis group. A fourth group, the manpower assessment group, combined the results from the three initial working groups to meet the overall project objectives, namely,

-To produce a forecast for solar-trained manpower needs.

-To determine the types of training required to produce manpower capable of performing the tasks identified in the task analysis.

Projections of Expected Demand for Solar Systems

It was the basic assumption of this project that the demand for solar manpower is a direct function of the demand for solar equipment. The forecast of demand for solar equipment is based on existing studies.

Selection of Data Base

All available market studies were reviewed and analyzed; however, only 1974 or later studies were sufficiently current to be considered for selection. The objective of this process was to obtain the best estimates of the number of solar units to be installed nationally, regionally, and state-by-state. The methodology and assumptions used in each study were analyzed to select the most reasonable approach to the problem. A decision was made to use three different studies as the basis of forecasts for the number of installations in this country.

These studies were as follows:

1. The University of New Mexico Study

   Title: The Economics of Solar Home Heating

   Date: July 1976

2. The MITRE Corporation (MITRE) Study:

   Title: An Economic Analysis of Solar Water and Space Heating

   Date: July 1977

3. The Solar Energy Industries Association (SEIA) Study:

   Title: Solar Market Capture and Market Penetration
   By Sheldon Butt

   Date: October 1976

The rationale for selection of the above studies is as follows:

The SEIA study is the industry's own estimate of its market penetration. As such, it represents the views of those who must directly gain or lose depending on the accuracy of their perception.

The MITRE study is the product of the most intense effort by DOE to date to arrive at feasibility and market penetration estimates. MITRE estimates are being used extensively by DOE in many other analyses.

The University of New Mexico study (UNM study) forecasts the economic feasibility of solar energy state-by-state, by year, and by application. Due to exogenous variables, such as orientation and structure, freedom from obstacles, and age of the structure, economic feasibility is not readily translated to market penetration. It was necessary, for this project, to carry out an assessment of market penetration, incorporating the economic feasibility as determined by the UNM study.

Figure 1 illustrates the major differences among the three studies selected and highlights the major assumptions each study employed. The studies produced several scenarios, each with its own assumptions. The UNM study, for example, had scenarios for two different interest rates and three different estimates of solar equipment costs. The most reasonable scenarios, in our opinion, were selected for presentation in the table. It should not be concluded that the three forecasts would be the same even if each of the three studies were based on the same set of assumptions. Different methodologies and, more importantly, different investment criteria, cause significantly different conclusions.

The UNM, SEIA, and MITRE studies provided regionalized results. MITRE used climatological data from sixteen different cities that represent sixteen different zones. SEIA similarly selected several regions for analysis and drew conclusions for the entire country. The UNM study provided analysis by state and by year. Since housing data are readily available by state, it was possible to make manpower forecasts, by state, for this project based on the UNM study.

Market Penetration

The fraction of the total housing market expected to have solar systems installed, when it is economically feasible to do so, is called the market penetration. The yearly market penetration for hot water and hot water/space heating systems for both retrofit and new installations are given in Figure 2. The assumptions and reasoning used to arrive at these ratios are also given.

The projected demand for solar equipment is substantial, based on three major market studies -- one produced by the MITRE Corporation, another by the University of New Mexico (UNM), and a third by the Solar Energy Industries Association (SEIA). All three studies agree that by 1985 there will be at least 2.4 million solar hot water/space heating units installed in the residential sector of the United States. Figure 3 compares the projections of solar installations by the three studies.

Manhour Requirements for Solar Energy Systems

The determination of manhour requirements per solar system is a key to estimating the future manpower demand for the solar industry. Information obtained by the equipment group indicates that the manhour requirements occur in four phases: design time, installation time, maintenance time, and repair time. These four different times can be determined separately since each is independent. The sum of these four times is the manhour requirement per system.

Time Definitions

Design time consists primarily of calculating heating load requirements, energy gain from insolation, choosing collector types and other factors concerning system design. The first solar system design a person performs will generally take longer than subsequent designs due to lack of experience. Furthermore, the design time requirement can be reduced by formulating tables of data used extensively in calculations.

Installation Time

Installation time is mainly hands-on time and requires knowledge of skills from various trades. This time depends greatly on the size of the system being installed, which includes the collector size, storage tank size, and other pertinent factors. Studies of solar energy demonstration projects and private installations indicate that the greatest varying factor in installation time is the total collector area, while the time for installing auxiliary components remains fairly constant.

Maintenance Time

Maintenance time depends more on the system complexity (whether a hot water only system or space heating and hot water combined system) than the system size.

Repair Time

The repair time depends on the type of problem encountered, which is totally unpredictable and uncontrollable, and therefore could only be estimated.

Factors Used for Time Determinations

To ensure proper determination of the times for each phase, the basic information used was as follows:

1. The solar energy system defined as the most "typical" system uses flat-plate collectors.

2. The typical solar hot water system has 50 square feet of collector area, while the typical combined space heating and hot water system has nearly 300 square feet of collector area.

3. The optimum collector size for each State is determined from the average daily insolation, weather data, and other collector characteristics for 75% of the heating load requirements of an average single family housing unit.

Installation manuals and operational procedures from various manufacturers providing detailed study of design procedures combined with the above information showed that the design time for each generic type of solar system should be relatively constant. The installation time should be a direct function of total collector area since there is little time variation in the installation of auxiliary components. Thus, it is necessary to determine how the installation time varies with total collector area. The maintenance time, similar to design time, is relatively constant because it is related to system type rather than total collector area or other factors. Since it is impossible to relate repair time with any predictable factor, it is plausible to assume no time for repair and to remain conservative in the estimation of manpower requirement per solar system. Thus, the efforts in this project were directed toward determining design, installation, and maintenance time.

Contractor Survey

A nationwide survey of solar contractors was made with better than 30% response. After preparing the data base, a statistical analysis was performed. There were some interesting results. The design time is constant for small variations in total collector area. For a typical domestic hot water system, the design time is between 15 and 18 hours. The design time for space heating systems varies greatly because all generic types were combined. (The installation time was found to be a direct function of total collector area.) For a typical domestic hot water system the installation time is approximately 64 hours, while for a space heating system it is between 120 and 183 hours. The maintenance time proved to be relatively constant for space heating systems while it varied somewhat for hot water systems. This is due to the variability in the maintenance data because no significant maintenance records have been kept to data.

It is important to note that the results obtained include the effect of overhead time, learning curve (experienced vs. non-experienced), generic type distinctions, and climatological effects. It was not possible to carry out statistical analysis by region because of a small-sample size.

Manufacturers and Distributors Interviews

Manufacturers and distributors were interviewed for design, installation, and maintenance time. It is interesting to note that manhour values for the three phases are consistently lower than the values derived by statistical analysis. The design time for domestic hot water systems is nearly two hours while the design time for space heating systems is 9 to 50 hours. This is substantially lower because a large part of design time may be absorbed by a manufacturer's design experts and computers, or distributors may handle the design for the brand of product they stock. Installation time ranges from 60 to 100 manhours for space heating systems. This broad range is expected because of the various types of solar equipment produced by manufacturers. The installation time for domestic hot water systems is from 16 to 24 manhours. The maintenance time is approximately 2 manhours per year for a hot water system and between 7 to 10 manhours per year for a space heating system. This survey has been quite useful in establishing that there is a definite overhead time.

In addition to these specific questions regarding design, installation, and maintenance time for solar systems, the contractors were asked for general comments on their need for solar-trained workers. These comments were helpful in providing project personnel with an insight into the problems facing the solar contractor.

Committee of Experienced Consultants

Persons were contacted who had designed and installed several systems and who are considered pioneers in the solar field. They were asked to define the time required in each phase for the typical domestic hot water system and the typical hot water and space heating combined system.

The concensus was that the installation time for a typical domestic hot water system is approximately 50 manhours in retrofit construction. For a space heating and hot water combined system, that time is approximately 132 manhours. For new installations these times could possibly be reduced by half, depending on the efficiency of the installers.

The design time is approximately 5 to 7 manhours for hot water and 20 to 30 manhours for space heating, if a designer has an adequate background and some experience in the field. The maintenance varies from system to system, but it is approximately 2 manhours per year for hot water and 10 to 15 manhours per year for space heating. Comparing these values with manufacturers' values it seems that manufacturers' suggested times in all phases may not account for overhead time and other factors. The variability of the data in the statistical analysis may also be explained in terms of differing efficiencies of solar installers.

Task Inventory

Using the times listed for each task in the Task Inventory, values for design time, installation time, and maintenance time for typical systems were obtained. The installation times for typical domestic hot water and for typical space heating and hot water combined systems are 46 and 127 manhours, respectively. These time-values are in agreement with values obtained by statistical analysis. The design times of 10 and 34 manhours for domestic hot water and space heating and hot water respectively, are also in agreement with the results of the statistical analysis. The maintenance time in this case is a little higher than that from the statistical analysis because the task inventory listed in detail all tasks required for maintenance rather than only those tasks that one would normally expect to encounter.

Combined Results

Combining the results obtained in each of the methods, the final values for manhour requirements for a typical solar system are shown in Figure 4.

Calculation of Manpower Requirements for the Domestic Solar Energy Industry

The conceptual formula used in this project for calculating the yearly manpower requirements (not incremental) is given as follows:

$$\text{Yearly manpower} = \frac{I_n \times (T_d + T_i)}{1735} + \frac{I \times T_m}{1735}$$

Where I_n = Number of installations in year n

T_d = Hours required to design typical system

T_i = Hours required to install typical system

I = Total number of solar systems installed to data

T_m = Average maintenance time per system per year

CGO

The figure 1735 represents the number of hours that the typical tradesman works per year according to the Bureau of Labor Statistics.

Manpower Forecasts Based on Three Market Studies

Based on the three installation projections, total manpower demands were calculated. These demands are plotted on a yearly basis in Figure 5. Calculations using data from the SEIA study give the highest figures showing a need for approximately 80,000 practicing solar workers in the field by 1985. Using data from the University of New Mexico, nearly 40,000 people will be working in the solar field in 1985. The most conservative calculations, using data from the MITRE study, indicate 25,000 people will be working in the field in 1985. Thus, it can be concluded from this project that, by 1985, at least 25,000 people will be working in the field as technicians and mechanics for design, installation and maintenance of solar equipment in the residential sector of the United States.

By 1990, this total manpower demand increases to a minimum of 50,000 workers, using data from the MITRE and University of New Mexico studies. According to the SEIA study, the manpower demand increases to 325,000 people by 1990.

The manpower demand using the University of New Mexico study as a base is shown in Figure 6 for space heating and domestic hot water systems and in Figure 7 for domestic hot water systems. These forecasts are by state, by year, from 1978 to 1990. The incremental manpower demand is shown on the bottom line. This number is the estimate of new workers required for the corresponding year.

SKILLS ANALYSIS

This project determined the expected time required to design, install, and maintain solar space heating and hot water systems. For this study, it was found that the typical installation time for a domestic hot water system is 40 manhours, plus an additional 10 manhours required for design, and 2 manhours per year for maintenance. The typical domestic space heating system requires 125 manhours to install, 30 manhours to design, and 10 manhours per year to maintain.

Using a task analysis approach all tasks required for a typical solar system were listed and analyzed.

Task Inventory

A task inventory was prepared which listed all the major duties and associated tasks for the design, installation, and maintenance of a solar domestic hot water heating and cooling system. Three questions were asked for each task statement on the Task Inventory Form.

1. How many people are required to carry out the task?

2. How much time is required to carry out the task?

3. How difficult is it for a person to learn how to do the task?

"Learning Difficulty" was denoted on three levels — 1, 2, or 3, depending on whether the task was 1 - easy to learn; 2 - moderately difficult to learn 3 - difficult to learn.

Task Analysis

The purpose of the Task Analysis was to provide a detailed listing of the steps typically performed for the design, installation, and maintenance of a solar system, so that a solar technology curriculum could be developed should the need for such a curriculum be established. This analysis also listed tools and equipment, materials and components, required science and mathematics and a performance objective for each of the duty statements.

Assignment of Tasks to Trades

Each task statement in the Task Inventory was labeled and attributed to the tradesman who normally or traditionally might perform that task. This made possible the formation of two matrices (Figure 8 and Figure 9) which can be used to compare the learning difficulty levels with the type of tradesman for solar design, installation, and maintenance. The times given apply to a system consisting of space heating plus domestic water heating. It is a "Typical" system utilizing 300 square feet of water collectors.

Trade Matrices

Down the left side of each matrix is listed the tradesperson who would be expected to do the type of work for each task. Across the top are the "Learning Difficulty" levels as given in column 3 of the Task Inventory. Each "level" is further broken down into Design, Installation, and Maintenance (denoted by Des., Ins., and Mtn.). In Figure 8, man-minutes are listed for a flat-plate, liquid system. These times were taken directly from the Task Inventory, and are listed on the matrix according to tradesman and learning level (which is further separated into design, installation, and maintenance). The percentages, shown in parentheses in each square, were obtained by summing all the times (Des., Ins., and Mtn.) in the square and dividing by the total job time, shown in the bottom, right hand square. In Figure 9 the same data are shown for a flat-plate, air system rather than liquid. Note that for the liquid system, no sheet metal man is required; however, a plumber is still required for the air system because of the need for domestic hot water. (The matrices do not include time for design or installation of the conventional auxiliary system; otherwise the HVAC and sheet metal personnel times would be increased significantly.) For either system, some interesting observations can be made. First, the "solar" skills are needed a little more than 20% of the time. Second, the HVAC journeyman skills are needed 5% to 6% of the time, predominantly during the design of the system for calculations of the space heating and space cooling loads. Third, plumbing skills for a liquid system are required approximately 55% of the time, and this same percentage applies to sheet metal skills for an air system. Last, electrician skills are required about 4% to 5% of the time, carpentry about 1%, and other (i.e., the homeowners, general laborer, commercial insulator, etc.)

skills are required about 10% of the time. Of the total time required, approximately 25% involves Level 1 tasks, 45% Level 2, and 30% Level 3. Also, of the total time, approximately 20% involves design skills, 70% installation skills, and 10% maintenance skills. It must be remembered that these figures apply to a "typical" system of approximately 300 square feet of collector area.

Conclusions Drawn From Matrices

An analysis of the tasks for design, installation, and maintenance for a typical solar system reveals that the solar tasks accounted for approximately 20% of the total task time. The remaining 80% of the tasks could be performed by solar-trained conventional tradesmen. The heating, ventilating, and air conditioning (HVAC) journeyman skills are needed five to six percent of the time, and are attributable mostly to design of the system. Plumbing skills for a liquid system are required approximately fifty-five percent of the time, and this same percentage applies to sheet metal skills for an air system. Lastly, electrician skills are required about four to five percent of the time, carpentry about one percent, and other skills about two percent of the time.

Using degree of difficulty and background knowledge required as the criteria, the solar tasks could be divided into two categories. Two types of solar workers were defined from the two categories of solar tasks: the solar mechanic and the solar technician.

The solar mechanic is defined as a conventional tradesman with knowledge of solar systems. This person is expected to perform entry level tasks of installation and routine maintenance.

The solar tasks to be performed by the solar mechanic are to:

- Mount each collector.
- Check normal positions of motorized valves and dampers.
- Monitor flowrates and temperature differentials to test system operation.

These solar mechanic tasks represent two percent of the total design installation, and maintenance time for a typical solar energy system.

The solar technician has knowledge and skills specific to solar system design, installation, and diagnostic troubleshooting. Specifically, his/her solar duties and tasks are to:

- Calculate hot water load.
- Choose collector type.

- Calculate solar gain on unit area basis.
- Determine maximum available collector area.
- Determine optimum collector area.
- Design fluid flow systems.
- Check out the system powered components.
- Calibrate and test solar temperature differential controls.
- Test system operational modes.

The educational background needed by the solar "mechanic" to enable him/her to learn the required solar tasks is as follows:

1. A high school education,
2. Experience primarily in plumbing (for liquid systems) or in sheet metal (for air systems).

Therefore, the educational background for the solar "mechanic" is nearly identical to that of the practicing plumber or sheet metal tradesman.

The educational preparation to enable the solar "technician" to perform the required tasks includes the following:

1. A high school education,
2. Basic mathematics,
3. Basic physics,
4. Basic computer programming,
5. Basic heat transfer theory,
6. Basic fluid flow theory,
7. Drafting/blueprint reading,
8. Sun/earth relationships and other environmental problems,
9. Basic engineering technology.

The education necessary for a solar "technician" exceeds that of a typical tradesman, and is beyond the high school level. The conventionally trained tradesman in plumbing, sheet metal, or heating, ventilating, and air conditioning cannot be easily upgraded to perform the tasks of the solar technician, which amount to approximately 20% of the total time required to produce a solar energy system.

The technician's tasks require design skills and thus demand scientific and mathematical knowledge.

Solar Technician Demand

Since 20% of the tasks performed on solar systems are at the technician level, the demand for solar technicians will comprise approximately on-fifth of the total manpower requirement. Thus, the demand for solar technicians will be at least 5000 in 1985, and nearly 10,000 in 1990, according to calculations based on the MITRE report. Based on the University of New Mexico and the SEIA studies, the demand is 8000 and 22,000 solar technicians, respectively, in 1985, and grows to 12,000 and 65,000 in 1990. These trends for solar technicians are displayed in Figure 10.

The regional manpower demand by state for solar technicians based on the UNM study is shown in Figure 11.

To supply the required number of solar technicians and mechanics at a steady rate, a minimum of 4000 workers must be trained every year to fulfill the increment in demand until 1985. Of these 4000 workers, at least 800 must be trained at the solar technician level every year. In the years from 1985 to 1990, the yearly rate of supply must be increased to nearly 6220 total workers including at least 1200 solar technicians.

CONCLUSIONS

A substantial demand for trained skilled workers to design, install, and maintain solar systems will develop concurrently with the demand for solar equipment. According to the three solar market projections used, there will be at least 2.4 million solar units installed by 1985. Accordingly, by that year there must be a minimum of 25,000 skilled workers in the solar field. One-fifth of these workers must be trained at the technician level.

Solar technician training will be equivalent in length and extent to that for HVAC technicians, approximately a two year program. There is no need for as comprehensive or as lengthy a training for workers in the solar mechanic class. Most solar mechanic training is being done and will be done by the solar industry manufacturers, distributors, and dealers, and through short courses and continuing education. However, there is a need for an educational training program for solar mechanics if the individual does not have previous knowledge and training in HVAC and/or plumbing.

To meet the demand for solar workers, approximately 80 schools, each graduating 50 solar technicians per year, will be needed between 1978 and 1985. To fill the yearly demand for technicians between 1985 and 1990, 40 additional schools will be required. The regional development of these schools should follow the regional demand for installations.

Regional feasibility of solar systems will determine regional manpower demand. Solar space heating will become economically feasible among the Canadian border states in the extreme northeast and north-central parts of the nation between 1978 and 1980. Between 1980 and 1985, the middle belt states will show increasing feasibility. As expected, far fewer space heating systems are forecast for the southern sun belt states. Solar water heating without space heating becomes feasible in a more scattered manner. The trend for implementation varies with insolation and electric rates since hot water needs are more uniform than space heating needs.

RECOMMENDATIONS

Recommend:

1. That the solar mechanic training programs now being undertaken by solar manufacturers, distributors, and some trade unions be continued. This training should also be conducted through short courses, continuing education programs, and certificate programs.

2. That the development of solar technician training programs begin immediately.

3. That the basic technician training program contain the flexibility to accommodate local/regional variations and future developments in the solar industry.

FIGURE 1.

ASSUMPTIONS OF THE THREE STUDIES

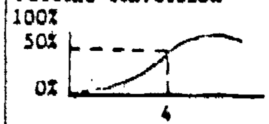
STUDY	COST OF SOLAR	INTEREST RATES	CONVENTIONAL FUEL PRICE	MARKET PENETRATION	TAX EFFECT
UNIVERSITY OF NEW MEXICO* *plus Navarro College's assumptions	H.W. $11/ft^2 + $300 20 year life S.H. $9.50/ft^2 + $1,100 fixed costs comparable typical unit, 30 year life	Real 2.5%	Computer analysis of lowest cost available fuel per M.B.T.U. by state (see table). Deregulation of natural gas.	Fraction of Market/Year H.W.: retro .018, new .27 S.H.&H.W.: retro .005, new .10 (year)	Present programs
MITRE	H.W. $20/ft^2	Real 4%	Assume price increase of electricity at 4% greater than inflation.	 	National Energy Plan (40% tax credit on 1st $1000. 25% on next $6400. Declines to 25%/$1000, 15%/$6400.)
SEIA	$1,150 H.W.	Equal to long term mortgage interest rates, unspecified.	Gas supply will diminish. Prices will increase. Implied assumption all new construction will be electric: 4.5¢/KWH increasing 5% greater than inflation.	Market Summary H.W. (retro / new) — S.H. (retro / new) 1982 77.9% 12.6% 3.2% 9.5% 1987 30.4% 7.6% 19.3% 21.1 1992 10.4% 3.0% 36.5% 7.9%	Assumes National Energy Plan (40% tax credit on 1st $1000. 25% on next $6400. Declines to 25%/$1000, 15%/$6400.)

FIGURE 2.

MARKET PENETRATION PER YEAR

	N.W.		S.H. & H.W.	
	Retro	New	Retro	New
Economic Rationality (including arch/aesth. considerations) (a)	.80	.80	.50	.50
Orientation & Struct. (b)	.50	.50	.30	.40
Age (retro-only) (c)	.67	N.A.	.67	N.A.
Free of obstacles (d)	.67	.67	.50	.50
10% (10 yr.) conversion (retro-only) (e)	.10	N.A.	.10	N.A.
YEARLY MARKET PENETRATION RATIO	.018	.27	.0050	.10

CALCULATION OF MARKET PENETRATION FACTORS:

(a) Econ. Rationality

- For H.W.: (new & retro): Only 20% of people will not "want" to spend the $1500, or are just against the looks of them.
- For S.H. & H.W: (new & retro): one-half the people will refuse to put out (or borrow) the money simply because of the large amount of dollars involved (approximately $6000+).

(b) Orientation & Structure

- For H.W.: Half the houses have orientation problems; no real struct. problem.
- For S.H. & H.W.: ½ have orientation problem.
  - Retro - Another 20% have structural or space problem.
  - New - 10% have space problem; no structural problems.

(c) Age

- Retro only: With 20 year solar system life, and 30 year house life, only 2/3 of housing still has necessary life left.

(d) Free of Obstacles

H.W. approximately 2/3 of all houses are free from trees, buildings, hills, etc. (S.H. has more of a problem because of more area).

(e) 10% Conversion (Retro only)

Approximately 10 years necessary to convert available market.

FIGURE 3.

COMPARISON OF NUMBER OF SOLAR SYSTEM INSTALLATIONS PROJECTED BY THE THREE STUDIES

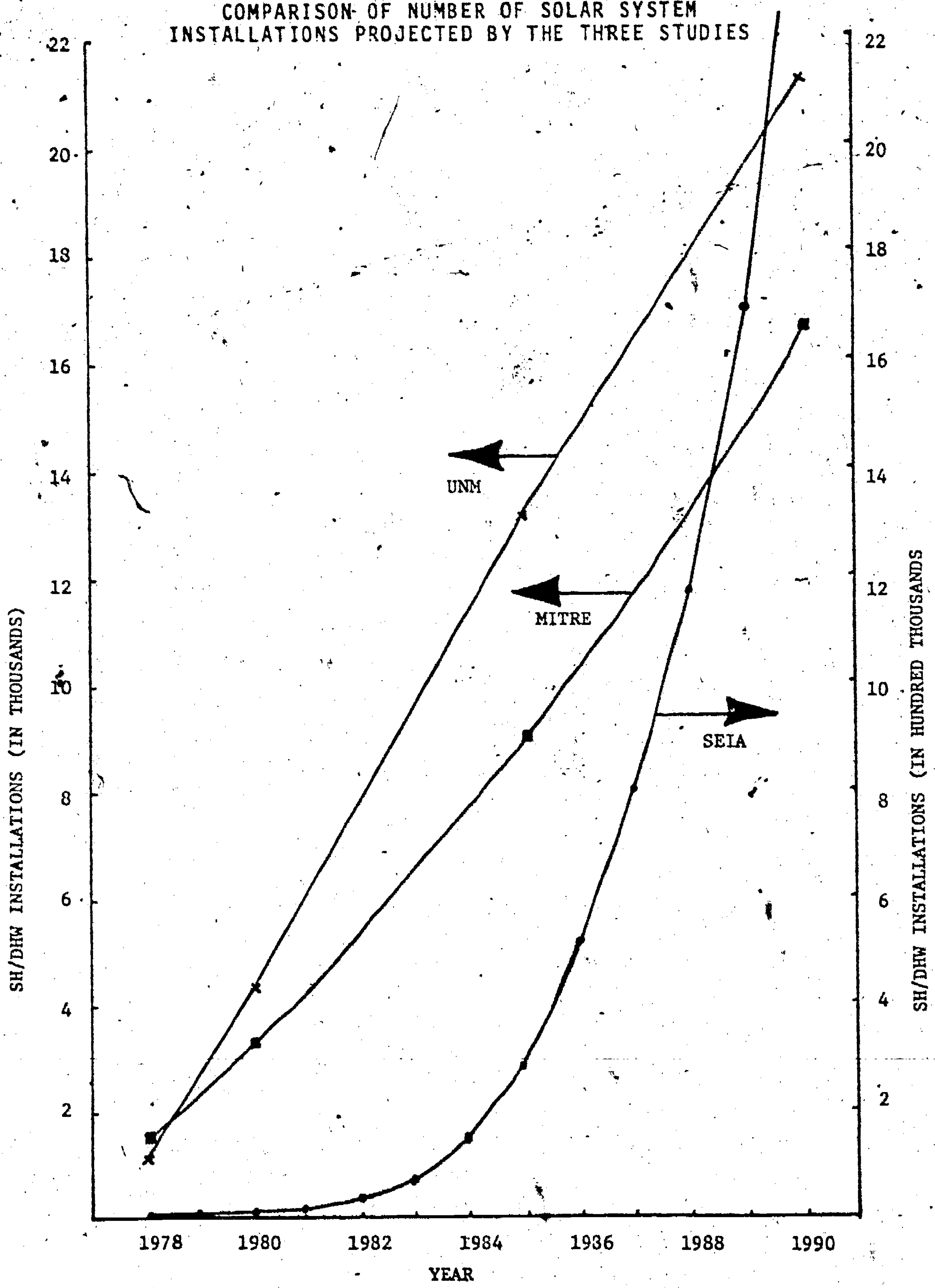


FIGURE 4.

MANPOWER REQUIREMENTS
FOR "TYPICAL" SOLAR SYSTEM

	DHW	DHW & SH
DESIGN	10 manhours	30 man hours
INSTALLATION	40 manhours	125 manhours
MAINTENANCE	2 manhours	10 manhours
TOTAL	52	165

FIGURE 5.
TOTAL MANPOWER DEMAND BY YEAR
(COMPARISON OF THREE STUDIES)

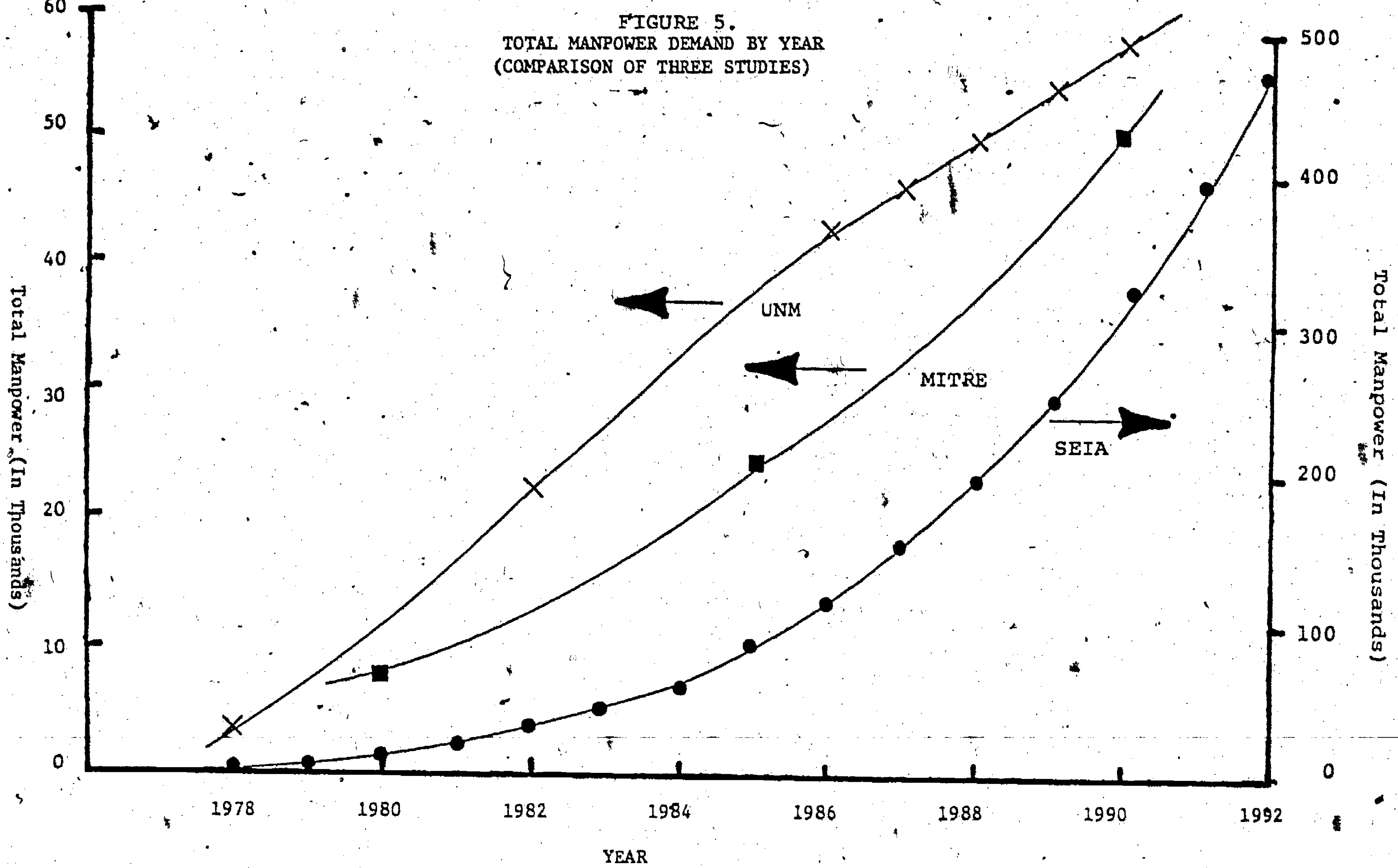


FIGURE 6.

MANPOWER DEMAND FOR SPACE HEATING AND DOMESTIC HOT WATER SYSTEMS BY STATE (In Thousands) BASED ON THE UNIVERSITY OF NEW MEXICO STUDY

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
AL														
AZ														
AR														
CA											3266	3478	3690	3903
CO								485	511	537	563	589	615	641
CT	550	575	601	626	651	677	702	727	753	778	803	829	854	880
DE								136	142	149	156	163	170	177
FL														
GA														
ID														
IL												2072	2165	2258
IN														
IA										1099	1149	1198	1248	1297
KS														
KY														
LA														
ME	36	44	51	59	66	74	81	89	96	104	111	119	126	134
MD									858	903	946	919	1034	1078
MA			895	936	976	1017	1058	1099	1140	1181	1222	1263	1304	1345
MI								2188	2284	2379	2474	2569	2664	2759
MN			894	933	972	1011	1050	1089	1129	1168	1207	1246	1285	1324
MS														
MO														
MT	134	140	146	153	159	165	172	178	184	191	197	203	210	216
NE									773	793	81[illegible]	833	854	874
NV														

FIGURE 6 (Continued)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NH	189	197	205	213	221	229	237	246	254	262	270	278	286	294
NJ						1276	1338	1401	1463	1525	1587	1650	1712	1774
NM							174	184	195	205	216	226	236	247
NY				2364	2466	2568	2670	2772	2874	2976	3078	3180	3282	3384
NC														
ND	90	94	98	102	106	110	114	118	122	126	130	134	138	142
OH													2379	2485
OK														
OR														
PA						2519	2632	2745	2858	2971	3084	3197	3310	3423
RI	136	143	149	155	162	168	174	180	187	193	199	206	212	218
SC														
SD		109	110	111	111	112	112	113	113	114	115	115	115	116
TN														
TX														
UT							218	229	241	252	265	276	287	299
VT	98	100	104	108	112	116	120	124	129	133	137	140	145	148
VA										1078	1146	1203	1259	1316
WA														
WV														
WI					330	344	359	373	388	402	416	431	445	449
WY			56	59	62	65	68	71	74	77	80	82	85	88
Total	1231	1402	3309	5819	6394	10451	10852	14547	16768	19596	23629	26599	30110	31269

FIGURE 7

MANPOWER DEMAND FOR DOMESTIC HOT WATER SYSTEMS BY STATE (In Thousands) BASED ON THE UNIVERSITY OF NEW MEXICO STUDY

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
AL									689	716	742	769	795	822
AZ				406	422	439	455	471	487	503	519	535	552	568
AR									420	436	452	468	484	500
CA				3586	3727	3867	4008	4149	4289	4430	3322	3419	3517	3614
CO														297
CT				461	477	494	511	527	544	561	578	594	611	628
DE	115	119	123	127	131	135	139	102	105	108	111	114	116	119
FL				1714	1781	1847	1914	1981	2048	2115	2181	2249	2315	2382
GA									908	943	977	1012	1046	1081
ID														
IL														
IN														
IA														
KS														
KY														
LA														
ME									152	157	162	167	172	178
MD				769	797	825	853	882	758	778	797	817	837	856
MA									762	789	816	843	870	897
MI														
MN														
MS									411	426	442	457	473	488
MO														614
MT														
NE														
NV				103	107	111	115	119	123	127	131	135	139	143

FIGURE 7 (Continued)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NH									142	147	152	158	163	168
NJ				1092	1133	797	824	852	880	907	935	963	990	1018
NM				173	180	[illegible]	135	139	144	149	153	158	163	167
NY	1911	1979	2047	1476	1523	1571	1619	1667	1715	1763	1810	1858	1906	1954
NC									1085	1126	1168	1209	1251	1294
ND									83	86	89	92	95	97
OH														
OK									591	613	635	657	679	701
OR														
PA									2051	2127	2203	2279	2355	2431
RI									124	128	133	137	142	147
SC				510	529	549	568	588	607	627	647	666	686	705
SD									102	106	110	114	118	122
TN														
TX									2308	2397	2485	2574	2663	2752
UT														188
VT									77	80	83	86	89	92
VA				977	1014	1050	1086	1123	1159	854	879	903	928	953
WA														
WV														
WI														731
WY														
Total New	2026	2098	2170	11394	11821	11872	12228	12600	22764	23198	22714	23435	24156	26708
Incremental manpower demand	+72	+72	+72	+9224	+427	+51	+356	+372	+10164	+434	-484	+721	+721	+2552

FLAT PLATE – LIQUID SYSTEM

	LEVEL 1			LEVEL 2			LEVEL 3			TOTALS		
	Des.	Ins.	Mtn.	Des.	Ins.	Mtn.	Des.	Ins.	Mtn.	Des.	Ins.	Mtn.
SOLAR	185	30	0	215	120	120	1175	240	0	1575	390	120
	215 (2.3%			455 (4.9%)			1415 (15.2%)			2085 (22.4%)		
HVAC	215	5	0	285	60	0	0	0	0	500	65	0
	220 (2.4%)			345 (3.7%)						565 (6.1%)		
PLUMBER	0	1200	560	0	2040	48	0	1200	0	0	4440	608
	1760 (18.9%)			2088 (22.4%)			1200 (12.9%)			5048 (54.2%)		
SHEET METAL	0	0	0	0	0	0	0	0	0	0	0	0
ELECTRICIAN	0	0	0	0	0	0	0	480	0	0	480	0
							480 (5.2%)			480 (5.2%)		
CARPENTER	0	100	0	0	0	0	0	0	0	0	100	0
	100 (1.1%)									100 (1.1%)		
OTHER	0	0	185	0	840	0	0	0	0	0	840	185
	185 (2.0%)			840 (9.0%)						1025 (11.0%)		
TOTAL	400 16.1%	1335 53.8%	745 30.1%	500 13.4%	3060 82.1%	168 4.5%	1175 38.0%	1920 62.0%	0	2075 22.3%	6315 67.9%	913 9.8%
	2480 (26.7%)			3728 (40.0%)			3095 (33.3%)			9303 (100%)		

FIGURE 8. – TRADE MATRIX, FLATE PLATE – LIQUID SYSTEM

FIGURE 9
TRADE MATRIX, FLAT PLATE - AIR SYSTEM

	LEVEL 1			LEVEL 2			LEVEL 3			TOTALS		
	Des.	Ins.	Mtn.	Des.	Ins.	Mtn.	Des.	Ins.	Mtn.	Des.	Ins.	Mtn.
SOLAR	185	30	0	215	120	120	1175	240	0	1575	390	120
	215 (2.1%)			455 (4.4%)			1415 (13.6%)			2085 (20.1%)		
HVAC	215	5	0	285	60	0	0	0	0	500	65	0
	220 (2.1%)			345 (3.3%)						565 (5.4%)		
PLUMBER	0	120	15	0	240	0	0	0	0	0	375	0
	135 (1.3%)			240 (2.3%)						375 (3.6%)		
SHEET METAL	0	1440	60	0	2820	0	0	1440	0	0	5700	60
	1500 (14.4%)			2820 (27.1%)			1440 (13.9%)			5760 (55.4%)		
ELECTRICIAN	0	0	0	0	0	0	0	480	0	0	480	0
							480 (4.6%)			480 (4.6%)		
CARPENTER	0	100	0	0	0	0	0	0	0	0	100	0
	100 (1.0%)									100 (1.0%)		
OTHER	0	0	185	0	840	0	0	0	0	0	840	185
	185 (1.8%)			840 (8.1%)						1025 (9.9%)		
TOTAL	400 17.0%	1695 72.0%	260 11.0%	500 10.6%	4080 86.8%	120 2.6%	1175 35.2%	2160 64.8%	0	2075 20.0%	7950 76.5%	365 3.5%
	2355 (22.7%)			4700 (45.2%)			3335 (32.1%)			10390 (100%)		

FIGURE 10
DEMAND FOR SOLAR TECHNICIANS BY YEAR,
COMPARISON OF THREE STUDIES

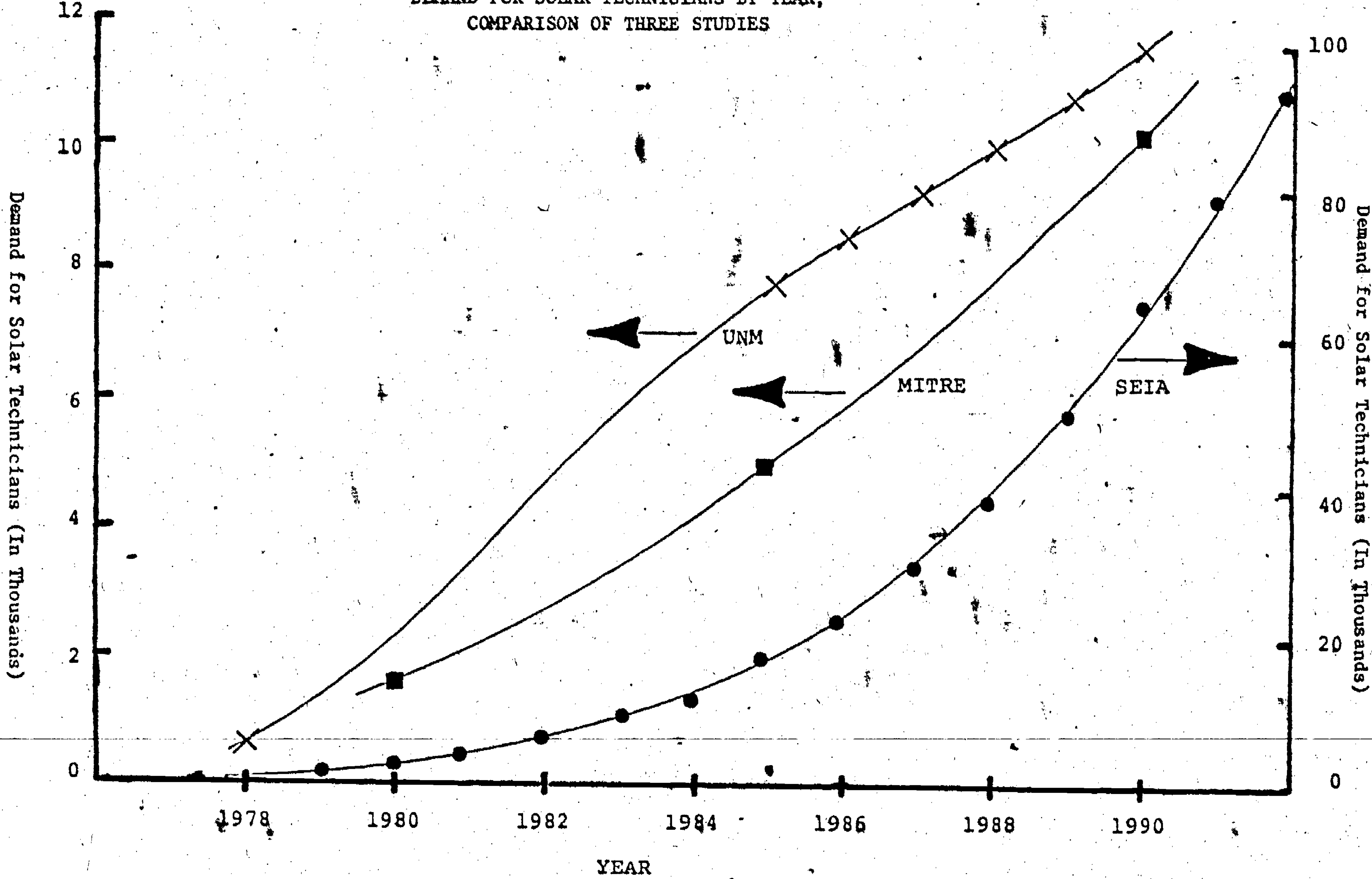


FIGURE 11

DEMAND FOR SOLAR TECHNICIANS BY STATE BASED ON THE UNIVERSITY OF NEW MEXICO STUDY

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
AL									138	143	148	154	159	164
AZ				81	84	38	91	94	98	101	104	107	110	114
AR									84	87	90	94	97	100
CA				717	745	773	802	830	858	886	1317	1380	1441	1504
CO								97	102	107	113	118	123	188
CT	110	115	120	217	225	234	242	250	261	268	289	284	293	302
DE	23	23	25	25	26	27	28	47	49	52	53	56	57	59
FL				343	356	369	383	396	410	423	436	450	463	476
GA									182	189	195	202	209	216
ID														
IL												414	433	445
IN														
IA										220	230	240	250	259
KS														
KY														
LA														
ME	7	9	10	12	13	15	16	18	49	52	54	57	59	63
MD				154	159	165	171	176	332	337	348	347	374	387
MA			179	182	195	203	212	220	380	394	207	422	435	448
MI								438	457	476	495	514	513	552
MN			179	187	194	202	210	218	227	234	241	249	257	265
MS									82	85	88	91	95	98
MO														123
MT	27	28	29	31	32	33	34	36	37	38	39	41	42	43
NE									155	159	163	167	171	175
NV				21	21	22	23	24	25	25	26	27	28	29

FIGURE 11 (CONTINUED)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NH	38	39	41	43	44	46	47	49	79	81	88	88	90	93
NJ				218	227	794	433	450	469	486	504	523	540	559
NM				35	36	37	62	65	68	71	74	77	80	82
NY	382	396	409	768	798	828	858	888	918	948	978	1008	1037	1068
NC									217	225	234	242	250	259
ND	18	19	20	20	21	22	23	24	41	42	44	45	47	47
OH														
OK													476	497
OR									118	123	127	131	136	140
PA						504	526	549	982	1019	1058	1095	1133	1171
RI	27	29	30	31	32	34	35	36	62	65	67	68	70	73
SC				102	106	110	114	118	121	125	129	133	137	141
SD		22	22	22	22	22	22	23	43	44	45	46	47	47
TN														
TX									462	479	497	515	533	550
UT							44	46	48	50	53	55	57	98
VT	19	20	21	22	22	23	24	25	40	43	44	45	47	48
VA				195	203	210	217	225	232	387	405	422	438	454
WA														
WV														
WI					66	69	72	75	78	80	83	86	89	237
WY			11	12	12	13	14	14	15	15	16	16	17	18