DOCUMENT RESUME

ED 205 757 CE 029 756

AUTHOR	Schachter, Mary
TITLE	The Job Creation Potential of Solar and Conservation: A Critical Evaluation.
SPONS AGENCY	Department of Energy, Washington, D.C.
PUB DATE	7 May 79
NOTE	25p.: This paper originated as part of a broader study on energy alternatives for the National Center for Economic Alternatives. Not available in paper copy due to broken print.
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Comparative Analysis; *Employment Opportunities; *Employment Projections; *Energy Conservation; Fuels; *Job Development; Labor Market; Labor Needs; Nuclear Energy; Power Technology; *Solar Radiation
IDENTIFIERS	Impact

ABSTRACT

Solar proponents claim that a solar- and conservation-oriented economy will create vastly larger numbers of jobs than the conventional and nuclear alternatives. Comparing energy alternatives in terms of job creation potential is tenuous at best due to the paucity of analysis in this area. Ideally, both the quantitative and qualitative aspects of job creation should be compared among alternatives. Due to the relative newness of the solar and conservation industries, however, only general comparisons of the direct employment impacts among energy alternatives can be made. A tentative conclusion from recent studies is that the general direction of changes in terms of direct job creation will be toward greater employment opportunities. A review of the literature shows that for the same amount of energy, solar creates 55-80 times as many direct jobs as natural gas. For the same amount of energy, conservation measures create 26 times as many direct jobs as natural gas at about one-ninth to one-fifth the cost. For the same amount of energy, solar heating systems create 2-8 times more direct jobs than conventional powerplants. Conservation measures create direct jobs at less than one-third of the cost/job of nuclear power and will be economical in all parts of the country. (YLB)

RECEIVED BY TIC 1979

THE JOB CREATION POTENTIAL OF SOLAR AND CONSERVATION: A CRITICAL EVALUATION

Meg Schachter
Department of Energy
Policy and Evaluation, Advanced
Energy Systems Policy Division

May 7, 1979

ACKNOWLEDGEMENTS

This paper originated as part of a broader study on energy alternatives for the National Center For Economic Alternatives. Many thanks to Gar Alperowitz, Co-Director of the Center, for enabling me to pursue my interest in this area of policy analysis.

Refinements to this work were done while under contract to the Department of Energy. The statements and conclusions presented here reflect the opinions of the author, and do not represent those of the Department.

Meg Schachter
May 7, 1979

The Job Creation Potential of Solar and Conservation: A Critical Evaluation

The development of solar energy and conservation in this country, as with all other recent forms of energy, has taken place in a political context. Early proponents focused on the use of solar energy as an inexhaustible source of energy which, compared to most conventional and nuclear alternatives, was environmentally benign. Together with conservation methods, solar technologies were seen to provide the needed alternative to a growing dependence on costly nonrenewable uranium and fossil fuels. These claims came in response to concern over emerging problems of environmental degradation and shortages of nonrenewable energy sources. Few solar technologies were actually used at the time, primarily due to the high costs of solar relative to conventional systems. Proponents asserted that the environmental benefits of solar and its inexhaustible nature more than outweighed the additional cost.

At present, many conservation methods and some important applications of solar energy are cost-effective to the energy user. Yet, due to subsidies to other energy forms, corporate control over fossil fuel sources, and a variety of institutional barriers, the implementation of solar and energy conservation is proceeding more slowly than simple cost-effectiveness criteria might dictate. As a result, the politics of conservation and, in particular, solar development have shifted to the issue of job creation. In an era where the private corporate economy seems incapable of creating sufficient employment, responsibility for job creation increasingly falls to public decisions. In this context, a significant advantage accrues to any energy source that can claim (legitimately or otherwise) that it is essential to increasing employment. Not surprisingly, solar proponents now assert that a solar and conservation oriented economy will create vastly larger numbers of jobs than the conventional and nuclear alternatives. Such assertions have not yet been comprehensively reviewed, although they are playing an increasingly political role. From the public policy perspective, high continuing unemployment dictates that we take seriously the employment effects of public decisions, particularly those as fundamental as energy policy. From the political perspective, it is important that the assertions of solar proponents be accurate, so that the other more positive aspects of a solar/conservation alternative (i.e., environment, cost, inexhaustible supply) are not discredited by politically exaggerated employment claims.

The purpose of this article is (1) to briefly outline a conceptual framework for comparing the quantitative and qualitative aspects of job creation among energy alternatives, and (2) to describe and evaluate the "state-of-the-art" of employment impact analyses. Hopefully, this discussion will provide solar proponents and public policy decisionmakers with a better understanding of the issues and trade-offs involved in making energy choices.

Part 1. A Conceptual Framework For Analysis[1]

Comparing energy alternatives in terms of job creation potential is an extremely tenuous process due to the paucity of conceptual and statistical analysis in this area. Ideally, one would like to compare both the quantitative and qualitative aspects of job creation among alternatives. For instance, several recent studies compute the number of jobs per energy output or the total cost per job as a basis for comparison. These quantitative ratios are useful if they are developed in a conceptually sound and consistant manner for each energy alternative. In addition to quantitative indicators, the qualitative characteristics of job creation should also be considered. A comprehensive employment impact analysis would compare job skill levels, the timing, stability and geographic distribution of jobs, displacement effects and the workplace environment.

The development of meaningful cost/job or jobs/energy output ratios require a clear understanding of what is meant by "cost", "energy output" and "jobs." Ideally, the cost figures should reflect total private and social costs associated with each alternative energy project, discounted over an equal time period.[2]

Private costs for residential solar or conservation programs would include: plant and equipment costs (where additional production capacity is needed), installation, materials, O&M, labor and return on capital (i.e., profit, rents and interest). Solar systems should also include the cost of storage and/or conventional backup power. For an electric powerplant, private costs would include fuel costs, plant construction, materials, general O&M, labor, utility company overhead, reserves, transmission and distribution costs and return on capital. In addition, the real resource cost of construction delays, due to lengthy siting reviews, public hearings and intervention, should be considered.

Social costs include all forms of public subsidization such as tax incentives (e.g., accelerated depreciation, deductions for intangible drilling costs, income and investment tax credits) and RD&D funding. They also include any social costs not reflected in private costs--such as the higher, real resource cost of energy (which is not entirely reflected in private costs due to Federal pricing policies and utility practices), or the costs associated with environmental degradation and occupational hazards.[3] On balance, conventional energy alternatives incur higher social costs relative to solar energy and conservation, particularly with the current level of Government expenditures to the nuclear, electricity, oil, coal and natural gas industries.[4]

The energy output figure should reflect the amount of energy saved or additionally supplied by the project. It is important, however, that all efficiency losses occurred during energy conversion and transmission be accounted for. In other words, the energy output figure should represent the average Btu equivalent of energy available at its end use.

Furthermore, the comparisons should be made between "perfect energy substitutes". It is clear that photovoltaics, which produces electricity, can readily substitute for conventional electric power. However, for industrial or agricultural users, who require a higher level of process heat than solar water or space heating systems provide, it is unclear that this assumption holds. Similarly, for residential users of heating oil or gas, photovoltaics might not be the appropriate substitute. In addition, powerplants generate energy capable of performing many more functions than space and water heating, and would be capable of meeting, except for rare power outages, the entire heating requirements of the home. All of the economically feasible solar units, on the other hand, still require some conventional backup heating system. In short, it is essential to consider the particular users and usages of a conventional energy system when evaluating potential energy savings or supplies from alternative sources.

The number of jobs required by an energy system is usually expressed in person-years (or job) or person-hours of work.[5] The total number of jobs created can be broken down into three basic categories:

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

2. Indirect employment, or the jobs produced in supporting industries required to provide materials and services for the energy systems, and

3. Induced employment, or labor required to meet the increased demand for goods and services generated by the increased capital and labor income associated with 1 and 2.

Conceptually, the third category of jobs is the least well understood. Basically, the theory of "induced employment" can be explained as follows: Some portion of the labor and capital income generated by an energy project will either be reinvested in productive equipment or saved. The other portion will be spent by labor, stockholders, rentiers, and the Government (i.e., as the recipient of increased tax dollars) on additional goods and services. This demand for goods and services will, in turn, generate employment. Eventually, savings and investment will also generate employment, although the timing of job creation is more difficult to determine.

Because alternative energy sources reduce the demand for conventional energy production, additional factors must be considered to arrive at a net employment impact figure. Such factors include the respending affects of the capital and fuel savings achieved, as well as jobs displaced where alternative technologies actually replace conventional systems. Moreover, any energy alternative that costs more per energy output and is made available to the public could decrease employment by diverting spending from other sectors of the economy, to the extent that these sectors are more labor-intensive.

Another issue to consider is the impact of alternative technologies on income distribution, savings and investment patterns, and economic growth. Technologies that result in a significantly different distribution of income between wage-earners and capitalists will have different effects in the national level of investment, economic growth and ultimately employment. While this effect may not be relevant in isolated instances of technological change, it is important when considering a substitution of solar and conservation for conventional energy alternatives on a national scale.

In addition to the quantitative impact, the qualitative impact of energy alternatives on labor must be considered. A comprehensive employment impact analysis would include such qualitative factors as: the skill and income levels of the jobs created, the time and geographic distribution of the jobs, the stability of the demand for labor, and the impact on the workplace environment and occupational safety. The skill levels required for alternative energy systems are particularly important when considering the displacement of labor employed in conventional alternatives. If solar technologies create predominately low-skilled jobs, for example, they offer limited job opportunities for skilled workers of a conventional power plant (although they could be appropriately targeted to underemployed areas).

Conceptualization is only one dimension of employment analysis, albeit an extremely important one. The other dimension is data analysis, which presupposes the existence of an accurate data base. However, unlike conventional energy production systems whose labor requirements and costs are known with some degree of certainty (even nuclear power has a history of costs), solar and conservation technologies are relatively new and commercially untested. These are nascent industries whose technologies and production efficiencies will change significantly with widespread application. This makes projections of costs and labor requirements extremely tenuous. Hence, the actual cost and magnitude of job creation in the solar and conservation industries is subject to error. Nevertheless, as discussed below, it is possible to make general comparisons of the direct employment impacts among energy alternatives.

Part 2: The Analytical "State of the Art"

Several recent studies have begun to generate useful data on the number and types of jobs associated with alternative energy technologies. In general, however, the analyses are incomplete and, in some cases, conceptually inaccurate. The following examples give an indication of the state of the art of employment impact analysis.

A study by the U.S. Office of Technology Assessment (OTA) has compared the direct labor requirements for a coal-fired generation plant with those for two solar energy systems.[6] For the conventional system, the analysis includes: all labor requirements for construction at the plant site, to build the 800-MWe turbine generator in a factory, to operate the generating facility at an average of 75 percent full capacity for a period of 30 years, to build a coal mine large enough to support the plant, to operate the mine, to transport the 2.5 million tons of coal per year needed to operate the plant, and to construct and maintain a transmission and distribution network. The labor requirements for the solar system include those for manufacturing and installing the collectors, routine operation and maintenance, and conventional backup over a 20-year system life. This is the only study I examined that attempts to estimate jobs associated with photovoltaics, an area of solar energy that has been virtually overlooked in job impact analyses. The study concludes from this comparison that "if all conventional power were replaced with solar units, labor requirements would be multiplied by a factor of 2 to 5. The multiplier would be even higher if a substantial amount of conventional generating equipment was required to provide backup of the solar system."[7] As discussed briefly above, the idea of "replacing" conventional power with solar assumes perfect substitutability. Unfortunately, the OTA analysis does not provide comparable cost estimates for these particular energy systems.

According to an analysis by Skip Laitner of Critical Mass, what is true for a coal-fired conventional plant is even more true for nuclear.[8] A comparison of the total requirements of a 1,000-MWe coal or nuclear powerplant calculated over the facilities' lifetime indicates that nuclear power requires 30 percent less direct labor man-hours than the coal equivalent. The study examines the construction and operation of 1,000-MWe single-unit powerplants run at a 75 percent capacity factor. The manpower used to construct the mining and processing facilities in the fuel cycle, the annual operating requirements of the fuel cycle, and the annual O&M of the powerplant are also examined. Laitner's analysis shows that, although the construction labor requirements are higher for nuclear powerplants, the manpower required for all other phases of the power system is higher for coal than for nuclear. It therefore follows that solar systems will require more direct labor than nuclear plants for an equivalent amount of energy. This conclusion is also supported by the studies discussed below.

In what is perhaps the most comprehensive analysis of this kind, the Council on Economic Priorities (CEP) is presently exploring the employment impact, relative costs, and energy savings/supply associated with conservation, nuclear, and solar energy systems on Long Island, New York. The CEP's Jobs Study is investigating the potential for a combination of conservation and solar energy applications as an alternative to two proposed nuclear powerplants.[9]

According to CEP's preliminary estimates, the combined solar/conservation option would generate 270 percent more direct employment and produce/save 206 percent more energy than the nuclear option at a lower total cost. For the solar/conservation option, total costs per person-year would be one-third as high as the nuclear option. It should be noted that the analysis omits backup power costs and employment.[10] In terms of equivalent energy output, the solar/conservation option also provides significantly more jobs than nuclear (i.e., 31 percent). As in the OTA study, Bensen's energy output comparisons assumes substitutability. This assumption is subject to criticism, however, since the residential sector currently uses oil, gas and non-nuclear electricity, and since relatively few new electric homes are expected to be built in the future on Long Island.[11]

The most interesting aspect of this analysis is that the solar/conservation "package" stands up to nuclear better than either of the individual components. For instance, a "solar alone" option would cost $10.96 billion to replace the nuclear energy equivalent of 0.88 quads, or about 60 percent more per quad. Inclusion of power backup costs would increase the expense of solar relative to nuclear. Furthermore, at electricity rates less than about $0.04/kWh, the solar option alone will not be economical on a life-cycle basis to the user.[12] A "conservation alone" option, on the other hand, would cost $2.44 billion to replace the nuclear energy equivalent, or about 64 percent less per quad. It would also be economical in all parts of the country.[13] <u>However, conservation alone creates less jobs per energy equivalent than the nuclear option.</u> The advantage of "solar alone" is that it creates nine times as many jobs/quad than nuclear. (Note that this comparison is consistent with OTA's findings). Hence, the optimal strategy is to implement a <u>combination</u> of solar and conservation measures which, together, can create more jobs and save energy at lower costs than nuclear. I will return to this issue in the discussion of FEA's energy conservation public works programs.

A draft study by the California Employment Development Department (EDD) makes similar comparisons between solar and conventional systems: however, their methodology is questionable.[14] The report compares the number of direct jobs that would be generated by constructing a proposed 1,900-MW nuclear plant and a proposed 400-MW combined-cycle plant with their solar energy equivalents. The solar "equivalent" to these plants represents the amount of energy from space and water heating units installed in homes and apartment buildings which would equal the average annual kilowatt hours the two plants would produce. It should be noted, however, if the number of solar units that make up the equivalents of these plants were actually installed, most of the energy displaced in California would probably be natural gas--not electricity. The report justifies this comparison on the grounds that: "In general, natural gas processing plants are much less labor intensive than electric plants, so the comparison with the solar equivalent would be even more striking."[15] Comparisons of the labor intensity of different sectors, as developed by the Lawrence Berkeley Laboratory, seem to support this conclusion.[16]

It is important to note that this analysis defines "direct" jobs in terms of construction or installation job requirements only. This is a much more narrow definition than the one used by OTA and other studies. It does not include job requirements for energy resource recovery, direct manufacturing (i.e., collectors and other solar components or turbine assembly), transmission and distribution and routine O&M. These omissions bias the analysis in favor of solar.[17]

With this caveat in mind, EDD's findings are presented in Table 1 below. Their estimates indicate that a solar equivalent will require 2 to 3 times more direct person-years than the Sundesert Nuclear Plant. For the Potrero Combined Cycle Plant, the findings are even more striking: The solar equivalent will require 8 to 35 more person-years. Unfortunately, the analysis does not systematically compare the costs of conventional power with its solar equivalent.

The EDD study also attempts to estimate the indirect and induced employment requirements using an employment multiplier, developed by the Argonne National Laboratory, of 2.2 total jobs for each direct job created in the manufacturing and construction industries in California.[18] The computational form of this multiplier is:

$$Es_i = a + B_1 x_{1i} + B_2 x_{2i} + B_3 x_{3i} + \ldots + B_n x_{ni}$$

Where Es_i is the amount of indirect and induced (i.e., nonbasic) employment in county i. The x_i represents two types of variables in this equation. The first type is the level of direct employment in each group of basic sectors in county i (i.e., agriculture and mining, manufacturing and construction, and transportation). The second type is special control variables which help to characterize the unique levels of indirect or induced employment in county i (e.g., average family income, student population, etc.). The EDD study uses a multiplier derived from B_2, which indicates the change in indirect and induced employment associated with a unit change in manufacturing and construction employment.

These regression multipliers are extremely useful in projecting the employment impact of a new basic industry in a specific community, county or state. However, they are essentially meaningless when comparing the employment impact of two very different technologies within the same basic industry category. Using the same multiplier for both conventional energy and its solar equivalent essentially assumes that (1) conventional powerplants create the same number of indirect jobs as their solar equivalents and (2) each energy alternative creates the same amount of induced jobs. That is, the labor and capital income provided by each alternative generates the same level of demand for the same goods and services.

The validity of these assumptions is highly unlikely, given the different materials requirements, labor intensities and skill and wage levels among energy alternatives. And, unless these differences are somehow accounted for, the comparison of total jobs between these energy systems will be precisely as enlightening as a comparison of direct jobs only.

This can be seen from Table 1, which presents EDD's estimates of total employment impacts. Note that the ratio of total jobs created by the solar equivalent (single-family residences) to those created by the Potrero plant is 35 to 1--the same as the direct job comparison. The comparison of total jobs between the Sundesert Plant and its solar equivalent is also similar to the direct job comparison[19] Thus, the employment multiplier used by EDD fails to enhance their employment impact analysis of energy alternatives. Until regression analysis is designed to differentiate among energy technologies, the use of multipliers will not reflect the differential impact on indirect and induced employment. Since the present "state of the art" is sorely lacking in this area, I will confine my comparisons to the impact of energy alternatives on direct employment.

TABLE 1

COMPARISON OF EMPLOYMENT IMPACTS: ELECTRIC POWERPLANT CONSTRUCTION VS. SOLAR SYSTEM INSTALLATION
(20 Year Life)

Project	Direct[a] Person-Years Required for Construction of Plant/Installation of Solar System
Sundesert Nuclear Plant (1,900 MW)	12,736
Solar Equivalent[b]	25,509-106,920
Potrero Combined Cycle Plant (400 MW) (gas and steam turbine)	428
Solar Equivalent[b]	3,579-15,006

Project	Total Person-Years (Direct,[c] Indirect and Induced) Required for Construction and O&M of Plant/Installation of Solar System
Sundesert Nuclear Plant (1,900 MW)	36,268
Solar Equivalent[b] (single-family residences only)	241,055
Potrero Combined Cycle Plant (400 MW) (gas and steam turbine)	1,237
Solar Equivalent[b] (single-family residences only)	34,385

(a) Direct refers to construction or installation job requirements only.

(b) Solar equivalent represents the amount of energy from space and water heating units installed in homes and apartment buildings which would equal the average annual kilowatt-hours produced in each plant. Higher bound represents an equivalent in single-family residential units only. The lower estimates represent multifamily buildings only.

(c) Note: The direct jobs here include O&M over the 20-year life. This makes the ratios between solar/nuclear and solar/combined cycle jobs slightly different from those above which include construction and installation jobs only.

Source: A Comparative Analysis of the Employment Effects of Solar Energy in California, (DRAFT) California Employment Development Department, 1977.

A final point concerning the use of state or regional multipliers is that their magnitude depends on the degree of diversification (i.e., how much material inputs are purchased within the region) and on the amount of capital "exported" out of the region. In fact, Argonne presents different multipliers for each state and subsections of states. Furthermore, the "national" multiplier will be higher than the multiplier associated with any one region. It is therefore important to clearly define the geographic boundaries of the analysis.

Another analysis of energy and jobs in California was developed by the California Public Policy Center (CPPC). In a study entitled Jobs Under The Sun, the CPPC analyzed the job creating potential associated with its SolarCal proposal.[20] As indicated below, the CPPC analysis is inaccurate and extremely misleading. Unfortunately, their conclusions are used indiscriminately by solar proponents to promote SolarCal and similar initiatives as the means to create several millions of jobs.

The CPPC estimates that SolarCal would generate about 1.1 million direct person-years (i.e., installation, collector and component manufacturing) over the 1981-1990 period. In addition, the CPPC projects "induced" employment by using the Argonne Laboratory multiplier of 2.2 (see above). It should be emphasized, however, that the multiplier is used incorrectly in CPPC's analysis. The 2.2 factor should be applied to direct jobs to yield total job requirements. In the CPPC study, however, the product is used to represent induced jobs and then added to direct jobs to yield total job requirements. In essence, this manipulation raises the Argonne multiplier from 2.2 to 3.2. The study also adds to that figure the jobs created in "distributional" functions such as design marketing, distribution and support activities. These jobs are estimated at 25 percent of total manufacture and installation, which effectively increases the multiplier to 3.45. In my estimation, the CPPC study grossly overstates the indirect and induced job requirements associated with solar systems. Furthermore, as discussed above, there are conceptual problems with using the Argonne multiplier (even correctly) to compare energy technologies. Therefore, the discussion of this study is limited to the estimates of direct job potential.

The CPPC estimates that the solar program would displace 8,627-12,430 bcf (about 8.6 to 12.4 quads) over the 10-year period. This translates into 88,710-127,907 direct person-years per quad. As indicated above, these estimates are lower than those developed by the CEP, although the job figures are not directly comparable.[21]

The CPPC did not provide an estimate of the cost for their program. However, elsewhere in their report, they propose another program costing $42.7 billion which would produce a total of 3,829,578 person-years. Dividing by their multiplier of 3.45, I estimate that this figure would translate into 1.1 million direct person-years (which is comparable to the figure given above) or $38,500 per direct person-years. This estimate is slightly higher than Bensen's preliminary estimate of $34,130. When Bensen's final report is available, a more detailed comparison between the two studies will be possible.

Although most comparisons to date have contrasted solar with nuclear or coal electric power, one of the more useful comparisons (particularly for California) is between solar and natural gas. The CPPC has recently compared the employment potential of constructing and operating a natural gas terminal to receive Alaskan and Indonesian LNG with that of building and installing solar systems to displace an equivalent to the LNG.[22] On the basis of reports by the California PUC, the CPPC estimates that the LNG terminal at Point Conception will generate 7,600 direct job-years over its 20-year life (at 1,600 construction job-years for 4 years, 50 terminal operation job-years and 10 pipeline maintenance job-years for 20 years). It would supply 9,490 bcf (cumulatively) over the 20-year period.

CPPC's SolarCal figures are used to calculate the number of direct solar jobs that would be generated by using active solar to displace an equivalent to the LNG case. As discussed above, solar would have generated 1.1 million direct jobs to displace 8,627-12,431 bcf. Hence, to displace 4,745 bcf over the 20-year period, the solar energy equivalent would generate 419,876-605,021 direct job-years. Since the study does not indicate the potential job creation associated with a 20-year solar program, I assume (as CPPC does), that employment is proportional to the energy displaced, regardless of time period.

The CPPC report also ventures a preliminary but useful total cost comparison among these alternatives. Projecting a total cost to consumers of $42.7 billion for the proposed LNG terminal over the 20-year life of the project (which would provide 474.5 bcf of LNG annually), the CPPC concludes that solar would displace 725.9 bcf/year for the same $42.7 billion investment. In other words, the solar option would generate 84-121 times as many jobs as LNG for an equivalent total cost while providing 53 percent more energy. Or, put another way, the solar option would cost 35 percent less and generate 55-79 times more direct jobs than its LNG energy equivalent.

It is important to note that the CPPC's projected cost of solar collectors ($10/ft^2) is one-fourth to about two-fifths the present average cost. Hence, these cost comparisons assume a significant reduction in solar collector costs over the period as a result of technical innovation and automation. If solar collector costs remain above $15/ft^2 (and LNG prices remain stable), then there would be no cost advantage to solar compared to its LNG equivalent--although the direct employment advantage would remain.

On the national level, the employment impact of a conservation program has been examined by the FEA (now the Department of Energy).[23] According to their analysis, a $1.65 billion expenditure on public works conservation programs could realistically produce 100,470 direct jobs over a 20-month period. These estimates relate to a program that includes retrofitting[24] all Federal buildings and one-half of all schools, colleges and non-Federal, non-profit hospitals; weatherizing 1.35 million homes occupied by low-income families and 50,000 HUD-owned homes; installing solar water heaters in 10,000 of the (weatherized) HUD-owned homes, and constructing 4,000 miles of bikeways.

If each "job" is assumed to represent a full person-year for each year of the program, then this program is expected to provide 167,449 person-years in direct employment over the 20-month period (124,333 unskilled, 15,999 skilled and 27,117 manufacture jobs). This translates into a cost/person-year of $9,850. Even under a conservative assumption about job duration, the costs/job are substantially lower than those associated with nuclear or LNG energy supplies.[25] In comparison to conventional domestic energy supplies, this conservation program offers the same number of jobs at about one-ninth to one-fifth the cost. In the extreme case of LNG imports (where most of the employment benefits are realized abroad), the cost per job is over 250 times the cost to produce a job in conservation. Although FEA's cost figures are low compared to Bensen's, it appears that, in general, conservation programs create jobs at a lower cost/job than conventional energy alternatives.

Furthermore, the $1.64 billion expenditure is expected to save about 0.1 MMBD, producing an approximate cost savings of $475 million per year.[26] In other words, the program would pay for itself in energy savings within 3 to 4 years. In order to compare the energy savings with the LNG alternative, I assume that a retrofit program will save 0.2 quads per year over the 20-year period (i.e., the life of the retrofitted buildings is at least 20 years), which would create 167,449 job-years and save about 4 quads over the period. This translates into a job/energy output ratio of 41,862/quad. This is over 25 times the job/energy ratio associated with the LNG alternative.

However, comparison between FEA's public works program and Bensen's nuclear option yields quite different results. I estimated that the nuclear option would actually create almost three times as many direct jobs as the conservation programs.[27] This comparison is particularly important: It indicates that conservation measures do <u>not</u> necessarily create more jobs than nuclear (or coal) for an equivalent amount of energy (in fact, the Bensen and FEA analyses indicate that the number of jobs is less). However, conservation <u>will</u> be more cost effective; that is, it creates these jobs at lower <u>cost</u>/job and cost/quad.

Two recent efforts have also included the <u>indirect</u> employment effects of solar energy in their comparisons. The Domestic Policy Review (DPR) of solar energy compared the direct and indirect employment effects of two accelerated solar energy scenarios (the Maximum Practical and Technical Limits cases) with base case employment over the 1978-2000 period.[28] The study examines the labor requirements of thirteen different solar technologies, taking account of the direct and indirect jobs displaced in the conventional energy sector due to increased solar penetration. The results indicate that total employment over the period for the Maximum Practical Case is about 3 million man-years higher than for the base case. For the Technical Limits Case, total employment is about 10 million man-years higher than in the Base Case. Although these results indicate that accelerated solar energy strategies would have a positive effect on overall employment, the magnitude of this effect is considerably smaller than those implied by previous, less complete analyses. The main reason for this is that the DPR did not limit its comparison to flat-plate solar collector systems, but included a variety of centralized, relatively capital-intensive solar technologies. It is important to note, however, that the DPR did not consider the relative costs of energy under each scenario, nor did it take account of labor-saving production techniques that would probably be necessary to meet the levels of accelerated demand for solar.

Preliminary results from an internal Department of Energy (DOE) analysis indicates that the installation of 2.2 million solar flat-plate collector units by 1985 will increase real GNP by less than 0.1 percent, and increase net employment in 1985 by 60 thousand man-years (0.1 percent increase over the base case).[29] This analysis includes the direct and indirect employment effects associated with flat-plate residential solar systems, but does not fully take account of the jobs displaced in the conventional energy sector. Furthermore, the analysis implicitly assumes that solar is cost-competitive with the conventional fuel it displaces, which may not be true for space heating systems by 1985. At the same time, however, it uses the labor-output ratios associated with today's higher cost systems. Both of these omissions could very well "net out" the slightly positive employment and GNP effects indicated above.

In addition to the three employment effects (direct, indirect and induced) described above, there is a fourth "substitution effect" associated with energy alternatives. To the extent that conventional or solar energy systems cost more, but are nevertheless made available to, and used by consumers, they will divert spending from other sectors of the economy. In almost all cases, this will decrease employment as energy (at higher prices) is "substituted" for other goods and services. This assumes that "other goods and services" are <u>more</u> labor intensive than the energy system. A recent comparison of labor intensities among personal consumption activities indicates that this assumption is generally true for electricity, gasoline and oil.[30] The CPPC study indicates that this assumption is valid for LNG as well. Solar technologies, however, appear to be the exception to the rule.

Conversely, a portion[31] of all solar savings achieved through the application of conservation or solar technologies (reflected in lower fuel costs, utility bills or capital costs) will be directly reinvested or respent in other sectors of the economy.[32] In almost all cases, these dollars will be spent or invested in sectors which have higher average labor intensities (and lower average energy intensities). This is because most of the dollar savings from conservation and solar are derived from reducing expenditures on direct energy (e.g., oil, gas, electricity, coal). And direct energy (in particular, electric power) has the lowest average labor intensities of almost all major consumer expenditures.[33] Thus, on average, it appears that "respending effect" will have a positive impact on employment.

Bruce Hannon incorporates this respending effect in his analysis of various conservation measures.[34] For the 1974 economy, Hannon calculates the changes in direct and indirect employment together with the respending effect for a number of energy-conserving "shifts" in consumer expenditures.

These include shifts from plane to train, throwaway to refillable beverage containers, car to train, truck to freight train, car to bus, car to bicycle, electric to gas stove and water heater, among others. By dividing the net change in employment demand by the net change in energy demand, Hannon arrives at a measure of the job potential per unit of energy saved. Unfortunately, his analysis does not include the direction or magnitude of the respending effect alone. Nevertheless, his conclusions clearly show that conservation has substantial employment potential--regardless of the direction of this respending effect. The largest net employment gains result from the substitution of intercity train use for plane travel (930,000 job-years per quad saved), for car travel (700,000), for owner-operated truck freight (675,000) and the substitution of throwaway to refillable beverage containers (750,000). Hannon concludes that full employment (defined as about 4 million unemployed) would be reached by reducing energy use 5 to 10 percent through the implementation of these energy-saving changes.

For cost-effective energy conservation alternatives, recent studies indicate that the total employment effects can be significantly positive. A study sponsored by DOE assesses the national employment effects of 1) imposing the miles per gallon (mpg) standards prescribed in the Energy Conservation and Production Act and 2) meeting a 90 percent housing retrofit goal where the retrofit is in compliance with minimum Federal standards under the National Energy Plan.[35] The study takes the direct and indirect labor requirements into account and "nets out" the jobs lost in other sectors of the economy (as, for example, when less steel is used in automobile production). It also estimates the employment generated as net energy savings are respent in the economy.

The results of this study indicate that, in meeting the mpg standards, net employment in 1985 will increase slightly, but significantly (i.e., by 10 to 20 thousand man-years). For the retrofit program, net employment in 1985 will increase by 70 thousand man-years (if homeowners finance the investment) to 520,000 man-years (if the government finances the retrofits through debt). Another recent study sponsored by DOE yields similar results for industrial cogeneration activities.[36] In this analysis, the effects of cogeneration induced from an additional Federal investment tax credit are expected to be quite small but distinctly positive. Real GNP in 1985 increases by $635 million (in 1972 dollars) and total net employment increases by 5,000 man-years over the base case. Unfortunately, the methodology used in both of these studies cannot estimate the longer-run effect of increased private or public debt on the economy. Nevertheless, these results illustrate that direct employment alone paints an incomplete picture of the total job creation potential of conservation measures, particularly those that are cost-effective.

A report by Len Rodberg for the Joint Economic Committee indicates just how powerful this "respending effect" can be for national employment.[37] Rodberg compares the employment effects of a conservation/solar scenario (CARE) to the base case for the year 1990. According to Rodberg's cost estimates, the CARE scenario will displace 45 quads of conventional energy in 1990, and save consumers over $50 billion in that year. Rodberg estimates that the respending of these cost-savings will account for about two-thirds of the total 3 million jobs created. It should be noted that Rodberg's analysis only looks at the cost savings for a single year (i.e., 1990), and hence ignores the higher costs (and their effect on employment) of solar/conservation during the early years of the program. Nonetheless the study serves to illustrate how important the respending effect (or, conversely, the substitution effect) can be in a comparison of employment impacts.

In examining the quantitative impact of energy alternatives, it is important to recognise the potential trade-off between the number and skill or wage level of jobs created. It is clear that for a given level of investment, more lower-skilled (and hence lower wage) jobs can be created than high-skilled jobs. As indicated below, most of the solar and conservation projects examined in this section represent systems with lower-skill requirements than conventional alternatives. It seems reasonable to expect, however, that the job creation potential of solar systems with higher skill and wage levels (such as community size and industrial systems) is lower than the small-scale alternatives. This is an important area for further analysis.

The skill levels required for alternative energy systems is particularly important when considering the displacement of labor employed in conventional energy production. According to the OTA and Skip Laitner's analysis, about 25-30 percent of the work required to build and maintain a conventional electric system is associated with conventional fuel supply. For natural gas production and delivery, the percentage is even greater.[38] Solar and conservation will effect these jobs by displacing fuel consumption. Furthermore, to the extent that these alternatives cut demand for peak generating capacity, they will also affect jobs in construction and O&M of generating equipment (about 40 percent of total work force). There is one job area, however, that solar and conservation are unlikely to effect: namely, transmission and distribution. Conventional energy backup--and hence distribution and transmission facilities--will be an economic necessity for solar space and water heating for the short and medium term. Hence, any solar (or conservation) alternative is unlikely to effect employment in this area, except in the extreme case when all or a very large fraction of local energy needs are met with solar.[39]

These considerations highlight the importance of examining skill level "mixes" associated with solar or conservation in direct comparison with the jobs they may displace. Unfortunately, current employment impact analyses are sorely lacking in qualitative comparisons. Nonetheless, some general observations can be made, based on preliminary analysis in this area.

Solar and Water Space Heating. Most of the employment directly created by a shift to solar water and space heating will be in the installation of the equipment by conventional building trades, and in the creation of new manufacturing industries. According to the OTA analysis, many of the skills required for installation of the equipment will be very similar to those required for conventional construction projects, although some brief training programs will undoubtedly be needed. The work will be nearly identical to the installation of sophisticated air-conditioning and heating systems in conventional buildings.[40] The CPPC jobs survey and a study done for the Sheet Metal Workers International Association by the Stanford Research Institute come to similar conclusions.[41]

However, it also appears that small-scale solar installations require a different "mix" of skill levels than conventional power. According to OTA, solar installations on individual buildings typically require one supervisor for each 10 workmen, while the ratio for the conventional coal equipment is closer to 1 to 3.[42] Hence, while small solar systems may enhance job opportunities for blue collar workers and for construction workers overall, higher level skill and wage categories may be displaced in the transition to solar energy.

The larger industrial and community solar systems, on the other hand, require much more professional work. They employ supervisors, managers, draftsmen, designers and engineers in roughly the same proportion as these skills are required in the construction of conventional power-generating facilities.[43] According to OT., these skill categories represent over 50 percent of total construction workers in a conventional plant.[44] Since many large solar facilities are likely to be supplemental to conventional boilers and generators, it follows that the solar equipment would simply add work in these areas at each installation. Thus, solar heating systems in these larger installations could also provide work for manual construction workers in the building trades (about 48 percent of total construction job requirements).

Employment opportunities in the manufacturing of solar collectors and components are more difficult to define. This is because the pattern of growth in the industry is presently unpredictable.[45] None of the studies I examined provided a detailed comparison of manufacturing skill categories. From the OTA analysis, it appears that solar heating systems provide about 3 to 4 times as many direct manufacturing jobs as conventional electric power for an equivalent amount of energy production. Without a more detailed comparison, however, this conclusion is tentative at best.

Targeting solar jobs to the unemployed has become a major objective of many job training programs throughout the country. However, a report by the Solar Energy Research Institute (SERI) indicates that only 18 percent of the jobs required for solar water and spcae heating systems are for semiskilled or unskilled labor.[46] These figures may come as a surprise to many advocates of training the unemployed to install solar collectors. The point is that we do not really know whether these trainees can be readily placed in solar-related jobs.

Photovoltaics (P/V). Analysis of the qualitative--as well as the quantitative--employment impacts in this area is highly speculative, since the manufacturing process will be changing dramatically as a result of technical innovations and automation. According to OTA's analysis, about 30-50 percent of the manpower requirements for current, tracking silicon photovoltaic systems is associated with collector and cell manufacture. Since P/V manufacturing currently involves a labor-intensive, handcrafted process, this proportion is expected to decrease with increased automation. Installation job requirements (currently 30-60 percent of total requirements) will probably involve the same types of skills required in conventional construction trades. Unfortunately, information on the relative proportion of skilled versus unskilled labor is currently unavailable. It is reasonable to expect, however, that the large, centralized P/V systems will require more professional work than small, decentralized applications.

<u>Conservation Measures for Buildings</u>. As in the case of solar heating systems, building weatherization projects will create new jobs primarily in the installation of materials (i.e., insulation, storm windows, weather-stripping, etc.) and in the manufacturing of these conservation measures is significantly different than those associated with conventional energy production. The FEA study indicates that unskilled jobs account for 70-80 percent of the total jobs associated with building retrofits and weatherization. Skilled jobs account for only about 8-10 percent in most cases--compared to over 40 percent in total job requirements for conventional energy production. On average, about 16 percent of all jobs are in manufacturing, compared to about 3 to 4 percent for conventional electric power. According to a survey by Lawrence Berkeley Laboratory, over 60 percent of manufacturing workers are low-skilled (defined as machinists, packagers, and warehouse loaders).[47]

In addition to examining the level and variety of job skills created, a comprehensive employment impact analysis should also consider the timing, duration and geographic distribution of jobs created. An energy project that puts a lot of people to work today is preferable to labor than one that creates a few jobs each year over a long period, particularly during periods of high unemployment. Conventional plant construction, as well as the widespread development of larger solar systems are preferred for this reason. Furthermore, jobs that can be readily targeted to underemployed communities and regions will ease structural unemployment. In general, small-scale solar and conservation programs are best candidates for this type of targeting--both because of their relative size and low-skill/wage requirements.

Unfortunately, none of the studies examined even attempts to analyze these qualitative aspects in a comprehensive way. None considers a specific mix of conservation and solar projects that could provide appropriate jobs for displaced workers of, for example, a nuclear plant. Nor do they compare the effect of energy alternatives on the workplace environment and on occupational safety. It is clear that qualitative analysis in energy and jobs remains one of the most fruitful areas for ongoing research efforts.

<u>Part 3: Conclusion</u>

While a number of recent studies have provided valuable insights, it can be safely asserted that the employment effects of alternative energy applications are not well known. Nevertheless, it is possible at this point to make some tentative conclusions. Specifically, it appears that the general direction of such changes <u>in terms of direct job creation</u> will be towards greater employment opportunities. In reviewing the literature on the subject, I found that:

- For the same amount of energy, solar creates 55-80 times as many <u>direct jobs</u> as LNG. However, at todays LNG and collector costs (or future costs greater than $15/ft.^{2}), solar will cost more to provide an equivalent amount of energy.

- For the same amount of energy, conservation measures (i.e., insulation, weather-stripping, storm windows, etc.) create 26 times as many <u>direct jobs</u> as LNG at about one-ninth to one-fifth the cost.

- For the same amount of energy, solar heating systems create 2 to 8 times more direct jobs than conventional powerplants. The upper bound represents a comparison with nuclear and, in my best estimation, with combined cycle plants. However, at todays collector costs and electricity rates less than about $0.04/kWh, solar will generally be uneconomical in comparison with conventional alternatives.

- Conservation measures such as direct insulation, weather-stripping, etc., create direct jobs at less than one-third the cost/job of nuclear power and will be economical in all parts of the country. However, they create less direct jobs than nuclear and other conventional powerplants per energy equivalent.

These findings lead to the conclusion that an "optimal energy strategy" would be to implement a combination of solar and conservation measures. This strategy would maximize direct job creation at lower total costs (and costs/job) than conventional alternatives. As discussed above, the overall effect of conservation or accelerated solar energy use on employment is intricately tied to the cost of these energy sources relative to conventional alternatives. Hence, the issue of energy and employment relates to the issue of how conservation methods and solar technologies can be made more cost-effective. Policies that promote cost reductions in the solar industry, reform electricity rates to reflect "marginal costs" and reduce the amount of subsidization to conventional energy will substantially improve the cost-effectiveness of solar and conservation in the future.

In sum, while the employment effects of alternative energy systems have not yet been determined with accuracy, preliminary analysis indicates that an energy strategy designed to promote the development of these industries would have a favorable effect on direct job creation. However, a word of caution is in order: Because direct employment effects are visible, they are likely to be the most useful in generating political coalitions among energy and labor activities. But if direct job creation is a misleading indicator of total job creation, successful coalition action may result in perverse policy decisions--which eventually hurt coalition constituencies and damage prospects for future coalition. In particular, it is important to ask whether or not the energy alternative encouraged through policy measures will cost the nation (or the region in question) more--and if so, how this additional cost will affect business activity and jobs. The dramatic need for both more employment and more enlightened energy policies underscore the need for continuing detailed analysis in the area of energy and jobs, with a clear understanding of its political context and limitations.

FOOTNOTES

1 Much of the conceptual framework used here was developed jointly with Michael F. Kieschnick.

2 The choice of a discount rate is a very controversial issue: it can range from zero (i.e., implying that we count costs to future generations equal to the way we count current costs) to the market rate of return on money (i.e., its private "opportunity cost"). All the studies I examined implicitly used a zero discount rate. In my estimation, these studies should explicitly state their reasons for doing so, and provide a sensitivity analysis of their results, based on different discount rate assumptions.

3 Another social cost that should be considered is the social "opportunity cost" of labor. For any project that employs the hard-core unemployed (e.g., small-scale solar or conservation systems), the social cost of labor will generally be significantly lower than the market wage rate. See: "The Private and Social Costs of Unemployment" by Martin Feldstein in: The American Economic Review, papers and proceedings. May 1978, pp. 155-158.

4 See: An Analysis of Federal Incentives Used to Stimulate Energy Production. Battelle Pacific Northwest Laboratories. March 1978.

5 Person-years and person-hours can refer to a variety of employee-time combinations. For example, two person-years can represent two persons working full-time for 1 year, or 1 person working full-time for 2 years.

6 Application of Solar Technology to Today's Energy Needs (draft), U.S. Congress, Office of Technology Assessment, June 1977, pp. VII-25-VII-35.

7 Ibid., pp. VII-27.

8 "Manpower Requirements for Nuclear and Coal Powerplants". Skip Laitner, editor of Critical Mass.

9. As of May 7, 1979, the final CEP study was not available in its entirety. The figures used here are based on testimony before the Joint Economic Committee in March 1978.

FOOTNOTES (cont'd.)

10 The inclusion of this factor is expected to widen the jobs/energy output gap, although the magnitude is unknown. The direction of change in costs/jobs is unclear, since both the numerator and denominator would increase. It seems unlikely, however, that inclusion of this factor would substantially narrow the gap between cost/jobs associated with solar/conservation and nuclear.

11 Conversation with John Stutz, Energy Systems Research Group. November 20, 1978.

12 This estimate is based on relatively high collector cost of \$43/ft.^{2}, which is probably appropriate for New York, but may be too high for other parts of the country.

13 According to Bensen's figures, conservation will be uneconomical (i.e., energy savings will be less than initial costs over the 30-year period) only if electricity costs less than \$0.4¢/kWh. This is clearly lower than any residential or commercial rate in the country.

14 <u>A Comparative Analysis of the Employment Effects of Solar Energy in California</u>, State of California Employment Development Department, pp. 27, October 1977.

15 <u>Ibid.</u>, pp. 16.

16 <u>Ibid.</u>

17 OTA's and Skip Laitner's analyses indicate that non-construction jobs for conventional powerplants represent 75-85 percent of direct jobs per energy equivalent. For a flat-plate or photovoltaic solar system, on the other hand, only about 30-50 percent of total direct jobs are non-installation requirements (see OTA and CPPC studies). Although the systems analyzed in the EDD study are not directly comparable to those examined by OTA and Skip Laitner, it can generally be concluded that EDD's methodology will significantly bias their conclusions in favor of solar.

18 <u>A Framework for Projecting Employment and Population Changes Accompanying Energy Development Phase I</u>. Argonne National Laboratory Energy and Environmental Systems Division. August 1976.

FOOTNOTES (cont'd.)

19 The ratios are slightly different due to the fact that direct jobs in table 4 include O&M over the lifeline; in table 3, on the other hand, the EDD excluded O&M.

20 California Public Policy Center, Jobs from the Sun: Employment Development in the California Solar Energy Industry. Project Dir.: Fred Branfman, Consultant: Steve Lamar (Los Angeles: California Public Policy Center, February 1978).

The objectives of SolarCal were (1) to retrofit solar space and hot water heaters on 75 percent of all single-family units and 95 percent of all multi-family residential units in California, (2) to require solar space and water heating on all single-family and multi-family units built after Jan. 1, 1985, (3) to retrofit 50 percent of all commercial space and mandate solar space and water heating on all new commercial buildings and (4) to annually displace 95 bcf of natural gas with solar in industrial processes.

21 CPPC's figures encompasse a wide variety of solar options, while Bensen's represent solar heating only. Furthermore, Bensen's figures include O&M, while CPPC's do not.

22 Ibid., pp. 84,88. The analysis is limited to LNG because as the report notes, imported natural gas from Mexico or Canada would enter California through already existing pipelines. Therefore, the use of these resources would virtually generate no new jobs in California.

23 The FEA analysis is summarized by S. Lynn Sutcliff and Allan R. Hoffman in a Senate Commerce Committee memorandum submitted to the Carter Transition Group (December 14, 1976).

24 Retrofitting measures include installing weather-stripping, caulking, insulation and double glazed windows.

25 For example, if a "job" is assumed to represent only one-half year employment for each project year--the costs/person-years are $19,700. This represents a lower cost/person-year than any other alternative examined.

FOOTNOTES (cont'd.)

26 The study assumes a cost of $13/bbl in 1976 dollars.

27 For this calculation, I assumed that the retrofits would last over a 30-year period, comparable to the nuclear plant-life.

28 Domestic Policy Review of Solar Energy. Final Report, Impacts Panel, Volume 1, Appendix A. U.S. Department of Energy TID-28835/1 (October 1978).

29 Macroeconomic and Sector Implications of Installing 2.2 Million Residential Solar Units. Analysis Memorandum (Draft 1978) by Ronald R. Earley, Malek M. Mohtadi et al, Macroeconomic Analysis Division, Energy Information Administration.

30 See: Energy Conservation: Its Nature, Hidden Benefits and Hidden Barriers. Lawrence Berkeley Laboratory. 1975 pp. 34.

31 Some of the income will be saved (e.g., in commercial banks) by consumers and only "indirectly" invested by others.

32 In some regions of the country, dollar savings will also be achieved for solar applications as an alternative to electricity.

33 Energy Conservation, Its Nature, Hidden Benefits and Hidden Barriers, op. cit.

34 "Energy Labor and the Consumer Society," by Dr. Bruce Hannon in Technology Review, March/April 1977. See also: "Conserving Energy While Increasing Employment," Dr. Bruce Harnon. Testimony before Joint Economic Committee Hearing entitled, "Creating Jobs Through Energy Policy," March 14-15, 1978.

35 Employment Impacts of Achieving Federal Energy Conservation Goals by Douglas Dacy, Robert E. Kuenne and Paul McCoy. Prepared for the Department of Energy by Institute for Defense Analysis (Arlington, Virginia, 1978).

36 An Analysis of the Macroeconomic Effects of Industrial Cogeneration Development Using Input/Output Techniques and the DRI Quarterly Macroeconomic Model. Prepared for the Department of Energy by JRB Associates (mcLean, Virginia, Sept. 1978).

FOOTNOTES (cont'd.)

[37] Employment Impact of the Solar Transition. Prepared by Len Rodberg for the Joint Economic Committee. U.S. Congress (April 6, 1979).

[38] See: Project Independence Task Force Labor Report Federal Energy Administration. November 1974, pp. 73-97.

[39] Application of Solar Technology to Today's Energy Needs, op. cit. p. VII-35.

[40] Ibid., pp. VII-32-33.

[41] Jobs Under the Sun, op. cit., pp. 22. Stanford Research Institute, Strategic Implications of Solar Energy for Employment of Sheet Metal Workers, H.W. Brock, G.R. Murray, J.D. McConnell, J.C. Snipes, Stanford Research Institute, Menlo Park, California; prepared for the Sheet Metal Workers International Association. Cited in Jobs Under the Sun, op. cit. p. 22.

[42] Application of Solar Technology, op. cit. p. VII-35.

[43] Ibid., p. VII-33.

[44] Ibid.

[45] Ibid.

[46] Solar Commercialization and The Labor Market. by Bert Mason, Gregg Ferris, Barbara Burns; Solar Energy Research Institute, SERI/TP-53-123 (Golden, Colorado; December 1978).

[47] Jobs Under the Sun, op. cit.