96th Congress }
1st Session }
JOINT COMMITTEE PRINT

EMPLOYMENT IMPACT OF THE SOLAR TRANSITION

A STUDY

PREPARED FOR THE USE OF THE

SUBCOMMITTEE ON ENERGY

OF THE

JOINT ECONOMIC COMMITTEE
CONGRESS OF THE UNITED STATES

APRIL 6, 1979

Printed for the use of the Joint Economic Committee

U.S. GOVERNMENT PRINTING OFFICE
39-666 WASHINGTON : 1979

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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LETTERS OF TRANSMITTAL

MARCH 30, 1979.

To the Members of the Joint Economic Committee:

Transmitted herewith for the use of the Joint Economic Committee and other Members of Congress is a study written for the Subcommittee on Energy and the Special Study on Economic Change entitled "Employment Impact of the Solar Transition," prepared by Leonard S. Rodberg.

This study is the first of two Joint Economic Committee studies to be released as part of the subcommittee's continuing exploration of the relationship between energy and employment and the SSEC's long-range analysis of the Nation's economy.

The views expressed in this study should not be interpreted as representing the views or recommendations of the Joint Economic Committee or any of its members.

Sincerely,

LLOYD BENTSEN,
Chairman, Joint Economic Committee.

MARCH 23, 1979.

Hon. LLOYD BENTSEN,
Chairman, Joint Economic Committee, Congress of the United States, Washington, D.C.

DEAR MR. CHAIRMAN: I am pleased to transmit herewith a study prepared for the Subcommittee on Energy and the Special Study on Economic Change entitled "Employment Impact of the Solar Transition." This study was written by Leonard S. Rodberg of the Community Energy Project, Public Resource Center.

Mr. Rodberg shows that the United States can expect a substantial employment payoff from an energy policy which stresses energy conservation and solar energy. If the Nation moves toward a high degree of energy productivity and a major reliance upon renewable energy, both of which are relatively labor intensive, we will achieve a noticeable reduction in unemployment. The net job creation in the year 1990 of a conservation and renewable energy strategy could reach 2.9 million jobs, according to Mr. Rodberg. Fuel consumption could be reduced by 45 quadrillion Btu's, a savings of $118.8 billion.

The author uses projections made by the Bureau of Labor Statistics to show where jobs would be created in the economy. A significant finding is that without a higher level of energy productivity we will be forced to accept a continued high rate of unemployment. Thus, a conservation and renewable energy strategy is integral to any successful full-employment strategy.

Achieving the ambitious energy and employment goals set forth in this paper will require a major Federal commitment. Both regulatory and financial mechanisms must be tapped to give energy users incentives to move away from an excessive reliance upon nonrenewable forms of energy. Easier access to credit for conservation and solar investments, for instance, would greatly aid in realizing the goals.

The findings of this study, of course, are those of the author and do not necessarily coincide with the views of the members of the Subcommittee on Energy.

Sincerely,

EDWARD M. KENNEDY,
Chairman, Subcommittee on Energy.

CONTENTS

EMPLOYMENT IMPACT OF THE SOLAR TRANSITION

(By Leonard S. Rodberg*)

SUMMARY

Faced with the increasing scarcity of oil and gas, the safety and environmental problems associated with coal and nuclear energy, and the rising price of all these nonrenewable fuels, the Nation is giving increasing attention to the conservation of energy and the use of solar energy in its various forms (solar heating and electricity, wind, biomass). In this study we estimate the impact on employment of the widespread introduction of energy conservation and solar energy measures, by envisioning a future in which there has been extensive investment in them and by using economic projections to estimate the employment resulting from such spending.

Conventional projections of energy consumption foresee aggregate U.S. energy demand doubling by the turn of the century. Over three-fifths of all energy use takes place in the industrial and commercial sectors, yet the major consumers of energy employ relatively few workers. This rise in energy consumption will be accompanied by a continuing shift in employment from the goods-producing to the service-producing sectors of our economy. New energy-related jobs, in these "business as usual" projections, will be few in number and will require worker migrations and social dislocations.

We examine an alternative scenario having a strong emphasis on energy conservation and solar energy. For residential and commercial uses, we postulate the introduction of rigorous insulation measures, improved equipment efficiency, the use of passive solar designs, and the installation of active solar water and space heating; for industrial uses, we assume more energy-efficient industrial practices, cogeneration of electricity as a byproduct of heat and steam production, and the use of solar collectors and solar-powered heat engines; for transportation, we assume increased automotive efficiency and use of mass transportation; for portable fuels, we assume production of methane and alcohol from biomass wastes; and for electricity production, we assume the use of photovoltaic cells, wind-powered generators, and solar-powered engine-generator systems.

For each of these measures, we assume a set of national goals to be achieved by the year 2000 and estimate the measure's cost per unit of energy saved each year after it is introduced. We postulate that investment in conservation and solar energy builds up over a 5-year period preceding 1985, with a constant level of investment thereafter.

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The employment generated by this investment is determined from economic projections and input-output tables developed by the Bureau of Labor Statistics of the U.S. Department of Labor. For the year 1990, we find an annual investment (in 1978 dollars) of $65.6 billion, 13 percent of the BLS projection for gross private domestic investment. This investment will create 2,170,000 jobs producing and installing conservation and solar measures and the components and raw materials they contain. One-quarter of the investment and jobs are in energy conservation, three-quarters in solar energy.

The introduction of these measures leads to very significant savings of nonrenewable fuels, reducing their consumption by 44.9 quads in 1990. Total energy consumption that year, including solar energy, is 76 quads, just about equal to the total consumption in 1977. One-half the saving is achieved through energy conservation, one-half through the use of solar energy.

These savings allow projected spending on nonrenewable fuels to be reduced by $118.8 billion in 1990, leading to 1,137,000 fewer jobs in the fuel-producing and electric generating industries. If these dollar savings are spent on other goods and services, an additional 1,870,000 jobs will be created in other industries. In net, 2,903,000 jobs will be created in this scenario, as compared to the "business as usual" projection. These jobs will tend to be dispersed widely across the country and can especially contribute to solving the chronic employment problem facing our urban areas. The emphasis on conservation and solar energy will also cause shifts in housing and land use patterns, inducing more compact communities and low-rise buildings.

The employment benefits and fuel savings can be achieved only if there is substantial investment in energy conservation and solar energy. This may require mandatory Federal standards and new financing mechanisms. Conservation and solar measures are purchased by the users of energy rather than the current energy producers. Since the user's investment is compared with the *average* cost of energy, while the supplier deals with the *replacement* cost of new facilities, which has been rapidly increasing, the user's decision tends to be weighted against the purchase. To overcome this, some alternative financing arrangement, such as federally backed, long-term, low-interest loans, may be necessary.

INTRODUCTION

Since World War II, American consumption of energy has tripled. [1] Total automotive horsepower increased seven-fold, home heating systems converted from coal to oil and then to natural gas, energy-consuming air conditioners and home appliances became commonly available, new commercial buildings incorporated artificial, energy-wasteful environments, airline travel expanded, and thousands of miles of highways were constructed. Overall energy consumption rose exponentially, climbing at a rate of 3.5 percent per year. Fossil fuels were consumed as if their supplies were limitless. Of course, they are not, and we now face the task of undoing the damage wrought in this 25-year binge.

An End to Exponential Growth

Beginning in 1970, domestic production of oil and gas began to fall. The natural limits on such nonrenewable fuels began to make themselves felt. The periodic winter gas shortages, the brown-outs, and the 1973 oil crisis are all symptoms of the dilemma we face, addicted to fuels whose supply is running out. With rapidly rising prices and diminishing reserves, we have to begin a comprehensive transition in the energy we use and the way we use it.

One approach which has strong support is through the expanded use of coal and nuclear energy, including the gasification and liquefaction of coal. However, both of these energy sources impose significant external costs. The extraction of coal, whether from underground mines or from the stripmining of near-surface veins, has serious deleterious effects on land, water, and agriculture; the conversion of coal to gas and liquid fuels consumes vast amounts of increasingly scarce water; and the burning of growing quantities of coal can have disastrous climatologic and health consequences. [2]

Likewise, the increasing use of nuclear energy poses a wide variety of serious social problems. With the growth of the nuclear power industry will come a significant likelihood of a reactor meltdown, with potentially catastrophic consequences for nearby population centers. Problems of waste disposal remain unsolved. Safety and environmental pollution difficulties are serious. The danger of nuclear weapons proliferation as a result of the widespread availability of plutonium and enriched uranium are fearsome. And, finally, the security measures necessary to avoid theft and sabotage could severely restrict our liberty. [3]

In the face of these mounting problems, an alternative must be sought. Such a policy would address the combined effects of declining supplies of oil and gas, higher fuel prices, dependence on imported oil, and worsening ecological problems in an environmentally benign and economically efficient manner. It would emphasize the conservation of

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energy and the replacement of the nonrenewable fuels with renewable energy sources, primarily solar energy. These so-called "soft technologies" would adapt energy production more closely to needs of the particular end use, rather than producing energy uniformly in a centralized facility. [4] They would include increased end-use efficiency, active and passive solar heating and cooling on individual buildings and neighborhood units, fuel production from biomass sources and wastes, and dispersed on-site photovoltaic and wind powered electric generation.

Advocates of the coal and nuclear route, with its implication of continued energy growth, argue that this approach, in spite of its potential costs, is essential for economic growth. As one advocacy group put it, "Growth in energy use is necessary to our national prosperity and to provide the jobs that are needed today * * * the relationship between energy availability and jobs is direct and inevitable." [5] Clearly, many people still believe that continued growth in our consumption of energy, and especially of the nonrenewable fuels—oil, gas, coal and uranium—is still essential if every American is to have a chance at the good life.

We will show in this paper that this view is not correct. We will demonstrate that it is possible to produce the same goods and services, and to achieve a higher GNP, by emphasizing the conservation of energy and conversion to renewable energy sources. Conservation and renewable energy can be major growth industries in the decades ahead, contributing both to the health of our economy and our citizenry. Introduction of a broad range of currently feasible conservation measures can simultaneously cut the consumption of rapidly depleting energy resources and create hundreds of thousands of new jobs. The expansion of solar energy programs can create a permanent substitute for declining reserves of non-renewable fuels and add millions of new jobs, particularly in urban areas where they are desperately needed. It can also reduce the outflow of dollars for imported oil and curb the inflationary effects of rapidly rising fuel prices. [6]

The Continuing Shortage of Jobs

The United States continues to experience a failure to provide enough jobs for its citizens, especially for minority groups who suffer the highest rates of unemployment. In 1978 the unemployment rate still stood at 6 percent, with black unemployment at 12 percent and teenage unemployment at 16 percent; "disguised unemployment" makes the real situation twice as bad. Economists do not see any prospect for an early improvement in this poor economic performance, and many foresee a downturn in the coming months which will make this situation even worse.

Many analysts argue that energy growth is crucial to a reduction in unemployment. In reality, the purpose of what we commonly call "energy" is to reduce the need for human labor, exacerbating the problem of providing jobs for a growing labor force. Industry has increased its output by drawing on the apparently limitless supplies of fossil fuels while shrinking its labor force. As the Congressional Office of Technology Assessment has commented, "The national energy policy of the last several decades has been to replace human labor as rapidly as possible with petroleum energy." [7] Thus the same practices which are creating the energy shortage have also been responsible for the shortage of jobs.

The ready availability of cheap energy has reduced employment opportunities in the energy-consuming industries and led to a continuing displacement of workers onto an uncertain job market. The energy industry itself cannot take up the slack; it employs a small proportion (historically, about 2 percent) of the labor force, and energy-related employment has not been growing. Both producers and users of energy have taken advantage of the ready availability of inexpensive energy supplies to introduce highly automated, energy-consuming production techniques, reducing employment per unit of output first in agriculture, then in manufacturing, and, most recently, in the service sector. The economy has not grown because of rising energy consumption, but in spite of it. Total employment has increased because the total output of goods and, especially, of services has increased and overcome the "labor-saving"—that is, employment-reducing—effects of rising energy usage.[1] [8]

The Nation thus faces two difficult but related problems, the continuing shortage of jobs and the coming shortage of energy. The purpose of this paper is to show, with a specific plan, how large-scale investment in conservation and solar energy can contribute to the resolution of both problems. Most projections show only slow growth for the renewable energy technologies. However, these projections tend to be self-fulfilling prophecies. By assuming slow growth, they inhibit investment and thus insure slow growth. We present a positive scenario that examines the implications of rapid growth, to stimulate discussion and interest in this possibility.

The slow-growth scenario is favored by many economists who view the introduction of solar energy at this time as economically "inefficient." They argue that, at current fuel prices, interest rates, and lending terms, the average consumer would, in many cases, experience higher annual costs for energy through such a purchase. However, when viewed from the perspective of national resource use, such reasoning is shortsighted. The results of this study show that, within a few years after the onset of substantial conservation and solar investment, the savings from reduced use of nonrenewable fuels will far exceed the investment, allowing funds to be shifted from energy into the purchase of other goods and services. The solar transition *is* economically "efficient."

In Part A we contrast the conventional projections of energy use and employment with the conclusions we reach assuming large-scale investment in alternative energy approaches. The reader interested in the detailed computations for this alternative approach will find these in Part B.

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[1] Economists often argue that such "labor-saving" measures increase economic "efficiency" by freeing workers to perform other necessary tasks. However, when the economy is not able to provide jobs for all who need them, and when energy supplies are limited, the opposite is true. If the workers who are displaced cannot find employment, they must be supported by unemployment insurance and welfare while being economically unproductive; those who do find employment will consume additional energy in their new jobs, thus accelerating the depletion of scarce energy resources.

Part A. OVERVIEW AND CONCLUSIONS

1. Baseline Projections: Business as Usual

Conventional projections of energy consumption assume that the past relation between gross national product and energy consumption will continue into the future. Recently they have been assuming a rise in the price of the nonrenewable fuels and, as a consequence, a slightly less rapid rise in demand for energy.

Until about 4 years ago, most projections of energy demand envisioned an aggregate demand by the year 2000 of 190 quads [1] per year, 2½ times our current consumption. Now, with evident signs of a decline in the rate of energy growth, projections are beginning to show more moderate increases. A "consensus" prepared by the Edison Electric Institute calls for consumption of about 150 quads in the year 2000, twice our current usage. [9] They assume continuing growth at a rate of about 3.0 percent per year, somewhat less than the pre-1973 growth rate of 3.5 percent but still a continuation of exponential growth. In spite of clear signs of an approaching price and supply crunch, they continue to assume that energy consumption will grow exponentially out to the next century. [10]

These "business as usual" projections of energy consumption assume that past practices will continue into the future and that new supplies of the energy sources we use today—coal, oil, natural gas, and uranium—will be discovered as current sources are depleted. They assume that alternative sources of energy—solar heating and cooling, wind power, etc.—will play a small role during this period, and they foresee an ever-growing consumption of the nonrenewable energy sources. As oil and natural gas become increasingly scarce and expensive, they forecast a shift to coal and nuclear energy and, especially, to electricity produced by these fuels.

In this study we will use, as our reference base, an energy projection prepared by Data Resources, Inc., for the period 1977–90 using macroeconomic assumptions developed by the Bureau of Labor Statistics of the U.S. Department of Labor. [11] DRI assumes that oil prices will rise 7.5 percent per year to $1.31 per gallon by 1990, while natural gas prices rise 3.5 percent per year to $3.76 per thousand cubic feet.[2] They then forecast an energy growth rate of 2.98 percent per year and total consumption of primary fuels in 1990 of 110.7 quads. Extended to the year 2000, this yields a total annual consumption at that time

[1] We use the common measure of energy output, the "quad," or one quadrillion (10^{15}) British thermal units (Btu). A quad is approximately equal to the energy supplied by 172 million barrels of oil, 42 million tons of bituminous coal, 0.98 trillion cubic feet of natural gas, or 293 billion kilowatt-hours of electricity. In 1977 the United States consumed 75.9 quads of primary fuels.

[2] Here, and throughout this study, we use 1978 dollars.

of 148 quads. In the DRI projection, the consumption of energy by sector and fuel type is as follows:

TABLE A-1.—ENERGY CONSUMPTION

[Quads per year]

	Coal		Natural gas		Petroleum		Nuclear		Hydro		Total	
	1977	1990	1977	1990	1977	1990	1977	1990	1977	1990	1977	1990
Household and commercial	0.2	0.1	8.3	9.5	6.6	8.8					15.1	18.4
Industrial	4.2	6.1	7.2	7.9	7.3	11.3					18.7	25.3
Transportation					19.2	21.0					19.2	21.0
Electric Utilities	10.3	21.9	2.4	1.2	4.6	5.3	2.2	13.3	3.0	4.3	22.5	46.0
Total	14.7	28.1	17.9	18.6	37.7	46.4	2.2	13.3	3.0	4.3	75.5	110.7

Consumption of every energy source increases, but coal and nuclear power meet most of the increased demand, largely through their use in electricity production. Nevertheless, petroleum and natural gas are assumed to be still available and, indeed, are consumed in even greater quantities than today. This is possible only because of the assumption that increasing quantities of these fuels are imported (e.g., 57 percent of the petroleum is imported). However, U.S. demand will be competing with the increasing demand from other countries, including growing Third World economies, and many analysts foresee a shortfall in world supply between 1985 and 1995. For instance, the Report of the MIT Workshop on Alternative Energy Strategies concluded that, even in its moderate growth model, "energy demand growth quickly outpaces plausible projections of potential supply. It follows that historically high growth rates of energy use * * * projected into the future are simply not realistic." [10] As noted in the introduction, this is just one of a number of potential barriers to this scenario.

The Historic Relation of Jobs and Energy

Over three-fifths of all energy use takes place in the industrial and commercial sectors, where goods and services are produced and workers employed. Yet, the major consumers of energy employ relatively few people. Between 1948 and 1970, energy use by the goods-producing sectors[3] rose 120 percent, while their employment declined 1.4 percent; by contrast, energy use in the provision of services increased 62 percent, but employment gained 75 percent. [12]

Six industries have historically consumed the lions' share of the energy used by industry. In 1968 (the year of the most recent detailed study of industrial energy use), the primary metals, chemical, food, paper, stone-clay-glass products, and the petroleum and coal processing industries used 68 percent of all energy used by industry, yet employed only 25 percent of all industrial workers and just 7 percent of the Nation's total work force. [13, 1] Between 1950 and 1971, their work force increased only 2.5 percent, while their energy consumption increased 106 percent. [14]

[3] In BLS categories, the goods-producing sectors are agriculture, forestry, fisheries, mining, construction, and manufacturing; the service-producing sectors are transportation, communication, utilities, wholesale and retail trade, finance, insurance, real estate, services, and government.

These relationships will probably continue in a period when energy prices are rising. The response of business to rising energy prices and the prospect of shortages is difficult to forecast, since we have not encountered such a period before. Economic projections must be made on the basis of the past, but we have evidence only from a period in which energy prices were falling and supplies were plentiful.

Much will depend on the response of public policy to this new situation, as well as on the overall economic environment. Businesses may reduce output, and thus their demand for labor, in the face of higher energy prices (the "income effect"), or they may call upon more labor and capital resources to replace energy (the "substitution effect"). Studies by Jorgenson and his coworkers suggest that the substitution effect will predominate, but only slightly. Using a model driven by cost-minimizing business behavior, they find that an average increase of 54 percent in energy prices will reduce energy consumption in the year 2000 by 38 percent and raise labor demand by 1.5 percent. [14, 15]

The Bureau of Labor Statistics of the U.S. Department of Labor carries on a continuing program of economic projections, in order to provide forecasts of labor demand in particular industries and occupations. [16] These projections are based upon expected levels of employment and labor productivity, with price variables playing a secondary role.[4] Thus, though they make use of the DRI projections to ensure that their predicted level of energy production is compatible with such "mainstream" energy forecasts, they do not incorporate the effects of rising energy prices on other categories of consumption. Nevertheless, since these effects are, at this point, uncertain but likely to be small—given sufficient time for adjustment to new patterns of consumption, new transportation modes, etc.—the BLS projections seem quite usable.

The BLS forecasts that the labor force will grow, between 1977 and 1990, from 99.5 million to between 113.5 and 125.6 billion. [17] This is an average growth rate of 1.4 percent, considerably slower than the 2.3 percent growth rate that characterized the 1970–77 period.

Within the BLS projections, the growing consumption of energy is not accompanied by a corresponding rise in employment in the energy industry or in the industries which use that energy. Rather, it leads to a continuing relative shift of employment away from these sectors to the more labor-intensive service sectors. The following table shows the projected change in employment shares, as civilian employment rises from 90.5 million to a projected level of 114.0 million:

TABLE A-2

	Increase in employment, 1977–90	Share of total employment (percent)	
		1977	1990
Goods-producing sectors [1]	4,797,000	26.8	25.5
Energy-intensive industries	(373,000)	(4.1)	(3.6)
Service-producing sectors [1]	18,352,000	71.2	72.6
Energy industry	351,000	2.0	1.9
Total	23,500,000	100.0	100.0

[1] The energy producing and distributing industries have been removed from these sectors and included with the "Energy industry."

[4] See Part B, Section 1, for a fuller summary of the BLS methodology.

More than three out of every four workers entering the labor force in this period will have to find a job in the service sectors where, quite frequently, wages are low and jobs provide less than full-time work. In 1976 the average wage in the service-producing sectors was $4.45 per hour, only 79 percent of the average wage in the goods-producing sectors. [1]

Bullard has argued that escalating energy prices will make "planned obsolescence" more expensive and will favor the manufacture of more durable products. [18] Manufactured goods will become more expensive relative to less energy-intensive services, consumers will buy them less frequently, and they will have to last longer and be maintained better. This will result in fewer assembly-line jobs and more maintenance and repair jobs.

The new jobs in the energy industry, which are of primary interest to us in this study, are largely related to the expansion of electricity production. They are jobs constructing the needed electric plants, mining and refining coal and uranium, and operating powerplants. It is characteristic of these occupations that large-scale migrations of workers will be required, as fuel sources in particular locales are exploited and then depleted, and as health and safety requirements demand the remote location of powerplants. These can impose severe dislocations and social costs on workers and their communities.

In general, this "business as usual" projection envisions an economic environment in which it will be difficult to achieve high levels of employment. With energy prices rising relative to other costs, increasing portions of the consumer's dollar will be taken up with direct and indirect energy costs. Until energy conservation measures can be undertaken, or alternative living modes adopted which can reduce energy consumption, relatively less income will be available for the purchase of other goods and services having a low energy, and high job, content. In this setting, conservation and renewable energy become essential parts of any strategy for full employment.

2. Toward Conservation and Renewable Energy

To avoid the manifold deleterious consequences of continued reliance on nonrenewable fuels, we must undertake an active program stressing conservation and renewable energy (CARE). There would be a strong emphasis on conserving energy, that is, on making the most efficient possible use of the energy we do consume, and on conversion of an increasing portion of our energy consumption from nonrenewable fossil fuels and uranium to solar energy in its various direct and indirect forms (solar heating, wind, biomass). Total fuel consumption would be capped and ultimately reduced, and the mix of energy sources would be changed, with an increasing portion coming from renewable sources.

The Conservation of Energy

In general, energy consumption can be reduced by (i) performing the same activity in a more energy-efficient manner, (ii) using energy that is now wasted, and (iii) changing behavior to reduce the need for energy. All three should be undertaken, though the last—involving modifications in our housing patterns, our transportation systems, the way we produce goods and services—will require more time to implement and more sweeping social changes. Our present patterns have been developed in an era when energy was cheap and its supply thought to be endless. As we realize that these conditions no longer hold, we may begin making significant changes in the way society organizes its living and working activities.

Very large savings appear possible even without this. With relatively modest efforts in the first two categories, savings approaching one-half of current consumption can be made. [19] There are great opportunities for energy conservation, not just because we have been using energy wastefully, but also because we have been using it inappropriately. We have been using fuels and processes which produce very high temperatures (hundreds or even thousands of degrees) to heat our homes 10° or 20°, with excess heat simply thrown out into the atmosphere. By producing energy that is tailored to its use, and extracting all the useful work from it, we can make significant gains over our past inefficient practices. Furthermore, conservation is not expensive; estimates of the cost of conservation measures range from one-half to one-tenth the cost of adding an equivalent amount of energy from new sources. [20, 21, 22]

It should be emphasized that, as we (and most analysts) use the concept, "conservation" does not mean the curtailment of energy-using activities. Rather, as the CONAES Demand and Conservation Panel defined it, conservation includes "technological and procedural changes that allow us to reduce demand for energy (or specific scarce fuels) without corresponding reductions in the goods and services we enjoy." [23]

New Sources of Energy

We will need some additions to our current supply of energy, not just conservation of what we use, and we will soon have to begin replacing fossil fuels with renewable sources of energy. We have to create an entirely new industry to produce, install, and maintain solar energy units of all kinds—hot water and air collectors and storage units, photovoltaic generators, biomass converters, wind machines, and so on. In the 1950's, a national decision created the massive Federal highway system and, in the 1960's, the space program. Each involved investments of billions of dollars and hundreds of thousands of jobs. In the same way, we need to move toward a national program of solar energy production and conversion. Solar energy could be the technology that lifts the economy out of the doldrums of the 1970's into a more prosperous period in the 1980's.

We will look at projections to the year 1990, assuming that such a program is initiated. As a baseline, we use BLS projections for the economy in 1990. The year 1990 may be looked on as a typical year in a 50-year transition from dependence on nonrenewable fuels to nearly complete reliance on renewable energy sources, primarily energy from the sun. Most homes, office buildings, and factories have useful lives of the order of 50 years. Thus, about 50 years are required to replace this building stock and convert it to energy-conserving, renewable resources.

One frequently hears expressions of concern for the employment impact of such alternative energy policies. These reflect doubts over the ability of the alternative approach to provide the energy that industry needs, in order to operate the machines on which many workers depend for their jobs. The approach adopted in this paper assumes that no policy will be adopted that does not provide sufficient energy to fuel the economy and, especially, its productive machinery. Thus the approach incorporates ways of substituting, step by step, renewable energy sources for nonrenewable ones. It assumes that there will be no reduction in the use of conventional energy sources, and no reduction in the supply of conventional fuels, at whatever price, until an alternative is available in sufficient quantity to meet the demand.

Elements of a CARE Strategy

An extensive range of measures can be encompassed within a CARE strategy. Those postulated to be installed and operational by 1990 include the following:

(1) For residential and commercial use:

Reduction of heat loss through additional insulation, efficiency improvements in the use of heating and cooling units, and careful attention to the flow of heat in the building and through its outer "envelope."

Improved energy efficiency of equipment and appliances.

Increased heat absorption from the sun through passive solar designs.

Solar water and space heating through active fluid collection and circulation.

(2) For industrial use:

More efficient industrial practices, recovery and reuse of waste heat, and use of recycled materials.

Generation of electricity as a byproduct of heat and steam production ("cogeneration").

Solar energy collectors and solar-powered heat engines.

(3) For transportation:

Increased automotive efficiency.

Increased use of urban mass transit and interurban rail and other energy-efficient modes of transportation.

(4) For portable fuels, production of methane and alcohol from agricultural and urban wastes.

(5) For electricity production:

Photovoltaic cells, including concentrators and cogeneration, on homes, commercial and industrial buildings.

Wind-powered electric generators.

Solar-powered heat engine-generator systems.

Other uses of solar energy, especially for cooling purposes, have not been included in the estimates made in this study because of the cost and underdeveloped nature of these systems. Similarly, capturing other forms of solar energy, such as ocean thermal energy, has been proposed, but such systems have not yet reached a sufficient stage of development to be able to estimate their energy and employment potential.

Energy Goals

The energy savings achieved, and the number of jobs produced by these measures, depend upon the scale of investment in them. For this

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study we assume a set of national goals, projecting the achievement of a specified level of implementation for each measure by the turn of the century. (With different goals, the results will be scaled up or down proportionately.) The goals we assume are the following:

TABLE A–3

Measure	*Goal for year 2000*
Residential use:	
Conservation	50 percent saving.[1]
Active and passive solar	100 percent of new homes; 50 percent of existing homes.
Commercial use:	
Conservation	50 percent saving.[1]
Active solar	50 percent of all buildings.
Industrial use:	
Conservation	40 percent saving by 1990.[1]
Cogeneration	100 percent of all usable sites.
Active solar	25 percent of all process heat.
Transportation	No specific goal.
Portable fuels	Conversion of 50 percent of waste products.
Solar electricity	25 percent of current electricity production.

[1] Energy saving goals refer to the consumption of delivered energy at the site of end use.

These goals are ambitious but achievable with the vigorous support of public policy.

CARE-Related Employment

To meet them, we assume that investment in conservation and renewable energy builds up over a 5-year period preceding 1985, with a constant level of investment thereafter.[5] This investment creates jobs which can be estimated using the input-output tables developed by the Bureau of Labor Statistics. These show the number of jobs in each industry required to produce a dollar of final output. (See Part B, Section 1, for further details and assumptions.) We find, for the year 1990 the following projections of investment and employment:

TABLE A–4

	Annual investment (billions, 1978)	Number of jobs (thousands)		
		Direct	Indirect	Total
Residential:				
Building conservation	$5.7	125	74	199
Appliance conservation	1.4	29	23	52
Passive solar	.7	15	11	26
Active solar	14.8	266	244	510
Commercial:				
Conservation	2.4	52	34	86
Active solar	6.6	119	109	228
Industrial:				
Conservation	1.5	20	25	45
Cogeneration	3.8	51	62	113
Active solar	12.1	163	198	361
Transportation				
Portable fuels	4.3	89	77	166
Electricity:				
Photovoltaics	3.6	69	53	122
Wind	5.3	91	81	172
Heat engines	3.4	31	59	90
Total	65.6	1,120	1,050	2,170

[5] Because of the need for further advances in technology, we assume that implementation of photovoltaics does not begin until 1985.

We distinguish the "direct" jobs involved in producing and installing the final products from the "indirect" employment involved in producing raw materials and components. The jobs projected here pay wages and salaries that are typical of the respective industries in 1990, especially manufacturing and construction. One-quarter of the investment and the jobs are in energy conservation, three-quarters in solar energy. About one-third of the investment is in the residential sector; the remainder of the investment must be made by business and government decisionmakers.

For comparison, the BLS projects the gross national product in 1990 to be $3,241 billion, with gross private domestic investment equal to $510 billion. Total employment will be 114,000,000 and total unemployment 5,400,000, with the BLS assumption of an unemployment rate of 4.5 percent. Construction employment will be 5,574,000 and manufacturing employment 23,872,000. Thus, conservation and solar employment will impose relatively small pressure on the economy as a whole, but it can make a significant dent in unemployment.

Energy Savings

These investments lead to very significant savings of nonrenewable fuel. Rather than including solar energy in the national energy accounts as contributing positive amounts of energy, there is less ambiguity if it is viewed as a conservation measure, enabling the consumption of nonrenewable fuels to be curbed. (The recently-enacted National Energy Conservation Policy Act includes solar energy and wind power devices among the energy conservation measures it promotes.) This method of accounting is especially appropriate for onsite solar techniques, where the energy supplied by solar devices is not transmitted, marketed, or even measured, but simply permits less dependence on external energy sources powered by nonrenewable fuels.[6]

Assuming that a strong CARE program is begun in 1980, we find that the fuel consumed in 1990, compared with the DRI business-as-usual projection, is as follows:

TABLE A-5.—PRIMARY FUEL CONSUMPTION

[Quads per year]

	DRI	CARE
Coal	28.1	14.2
Natural gas	18.6	11.5
Petroleum	46.4	33.6
Nuclear	13.3	2.2
Total	106.4	61.5

The implementation of these CARE measures leads to a saving of 44.9 quads of nonrenewable fuels.[7] Projecting forward to the year 2000,

[6] Steve Baer has pointed out, for instance, that anyone who dries clothes on a clothesline will be using solar energy. As compared to the user of a gas or electric dryer, they will be using less fuel but not necessarily less energy. And the energy, of course, is not measured.

[7] It might be thought that we should add the fuel consumed in the course of manufacturing and installing the conservation and solar systems. However, we have no way of knowing whether this production is part of the production already included in the BLS projection, or is an addition to it. In any case, this energy "investment" is "paid back" by these systems in a year or two and thus represents 5–10 percent of their useful energy delivery. [24]

with CARE measures implemented according to Table A–4, we obtain a total fuel consumption of 52.7 quads, little more than a third of the 144 quads found if the conventional, business-as-usual path is followed. About half the savings are achieved through conservation measures, half through solar energy.

The conventional method of energy accounting would add to the energy sources shown in Table A–5 the contribution of hydropower and various active solar systems envisioned in this scenario. Using this approach, we find for 1990 the following:

TABLE A–6.—ENERGY CONSUMPTION

[Quads per year]

	DRI	CARE
Nonrenewable fuels	106.4	61.5
Hydropower	4.3	4.3
Solar systems		10.2
Total	110.7	76.0

Total energy consumption in the CARE scenario is just about equal to total consumption in 1977; that is, there is zero energy growth between 1977 and 1990. Solar systems provide 10.2 quads or 13 percent of the energy in 1990, and they provide 22 quads or 28 percent of the energy in 2000. (This understates the significance of solar sources; to the extent they substitute for electricity produced from nonrenewable sources, 1 Btu of solar energy replaces 3.4 Btu of nonrenewable fuels.) For comparison, ERDA Report No. 49, the National Solar Energy Research, Development, and Demonstration Program, projected a solar contribution of the order of 10 quads by the turn of the century; the Stanford Research Institute found 15 quads in its "solar emphasis" scenario; the Mitre Corp. projected 6 quads; the Committee on Nuclear and Alternative Energy Systems (CONAES) of the National Academy of Sciences found a high-solar scenario yielding 14 quads; and the Council on Environmental Quality projected 15–25 quads. [23, 25, 26, 27]

Net Job Creation

The savings achieved by introducing this wide range of conservation and renewable energy measures allows spending on nonrenewable fuels to be reduced by $118.8 billion compared to the BLS projection for 1990. We estimate that this will lead to 644,000 fewer jobs operating and supplying facilities that use and distribute nonrenewable fuels and 493,000 fewer jobs in electric powerplant manufacture and construction. Of the total of 1,137,000 jobs, 680,000 are directly in these industries; 457,000 are in industries that are indirectly affected by these energy savings.

By 1990, the money saved by residential, commercial, and industrial consumers from reduced fuel consumption greatly exceeds the amount invested annually in CARE measures. These extra funds can be spent to purchase additional goods and services. From the net spending of $53.2 billion ($118.8 billion less than the annual CARE investment of $65.6 billion), there will be an additional 1,870,000 jobs created. The

BLS projections assume that the cost of energy rises no faster than the general rate of inflation, which they project at 5.4 percent per year. Since the price of these fuels will very likely rise faster than this, the dollar savings will probably be greater and the number of jobs created by the shift in spending correspondingly larger. Also, to the extent that CARE investments are made out of borrowed funds rather than current income, there would be more disposable income available and, consequently, more jobs produced. On the other hand, if fuel prices are raised by their suppliers in response to the drop in demand, there would be fewer additional jobs.

Keeping in mind these caveats regarding this estimate of the jobs created (and indeed, the approximate nature of all of the estimates in this study), we then have the following net job creation:

TABLE A-7

	Number of jobs created
Conservation	521,000
Solar energy	1,649,000
Nonrenewable fuels	−1,137,000
Added disposable income	1,870,000
Total	2,903,000

These figures do not include the additional jobs that would be created through the multiplier effect (spending of the income earned through this employment) and the accelerator effect (increased investment induced through anticipated growth). Such effects result from a stimulus added to an existing economic situation, whereas many of the jobs envisioned here may be part of the employment growth projected by BLS. To the extent they are not reflected in those projections, but represent additional investment beyond that in the BLS forecast, there would be a roughly equivalent number of additional jobs created through the multiplier (respending) effect.

The CARE Employment Picture

It is now widely recognized that employment programs must be "targeted" to be effective, that is, they must place funds and jobs in the regions, and among the population groups, suffering the most from unemployment. Jobs in the fuel extraction industries (coal mining, oil and gas exploration, etc.) and in powerplant construction tend to be far from the areas suffering the most severe unemployment. On the other hand, energy conservation and solar energy system production and installation will take place largely in settled urban areas where the unemployed reside and where they can easily be trained and hired. Thus, the jobs created in this scenario can make a significant contribution to solving the chronic unemployment problem facing our urban areas. Some jobs, such as those involved in producing photovoltaic arrays and solar heat engines, will be in more centralized manufacturing facilities; these can replace the jobs displaced by the reduction in conventional energy investment and production.

The jobs will be dispersed as widely across the country as are the dwellings people live in and the sites of their work. Workers will not be required to move to remote or temporary construction sites. Energy conserving technologies tend to be decentralized, geographically distributed in roughly the same proportion as the population. Fuel supply technologies, on the other hand, tend to be centralized and located where the fuel sources are, e.g., in Alaska, offshore, in the Rocky Mountains or the northern plains.

Jobs will be created in insulating and retrofitting homes with solar units, manufacturing and installing more efficient heating and cooling systems, making office buildings more energy efficient, producing and operating mass transit systems, producing and installing cogeneration devices, and recycling valuable materials. The skills required will be similar to those required for conventional construction projects and heating system installation. Work will be provided for sheet metal workers, carpenters, plumbers, pipefitters, construction workers, and production line workers of all kinds. Energy management will be increasingly important and will be a new source of employment for engineers and designers. Also, solar energy technology is suited to community-based enterprise and small business. Expansion of this industry will open up opportunities for ownership and economic development by those who now have little or no role in the multinational energy industries.

As energy conservation and the use of renewable energy become guideposts for community planning, land use and housing density patterns will shift. Higher densities, with a reduction of suburban sprawl, will reduce transportation energy usage and allow more energy-efficient housing construction. [28, 29] Compact communities will facilitate the introduction of neighborhood-scale solar units for both heat and electricity generation. [4] Such units have a number of significant advantages, including the possibility of utilizing shared community spaces with protected access to the Sun and of incorporating very large storage tanks that can store summer heat for winter usage. Very high densities (especially buildings of four or more stories) will be discouraged, since the solar resource is relatively diffuse (requiring about 400 square feet per family) and on-site energy supply would then become infeasible.

Commercial and industrial activities will require more energy planning and more land for access to the Sun. (In a solarized society, land becomes an energy resource.) Though these activities may occupy a small fraction of a community's land, their solar energy needs will require several times the space they occupy. [29] There will have to be community- and region-wide planning to insure that the necessary space is available, whether on buildings or on open spaces. There may also be a tendency for energy-intensive industries to locate in areas having large amounts of annual solar radiation, though increased transportation costs may tend to counter such shifts.

In general, energy considerations will become a predominant consideration in land use planning, community organization, and the location of jobs.

3. Financing the Solar Transition

Achievement of the scenario envisioned in this study, and of the job creation it would generate, depends on political and economic decisions which induce the necessary investment and make available the necessary funds.

It seems likely that this will not occur unless mandatory Federal standards are established governing a broad range of energy conservation and renewable energy measures (similar to the mileage requirements now imposed on automobile manufacturers). Even though price factors alone would appear to impel the introduction of these measures today, in fact, a great many of those with the ability to introduce them have not done so. The builders of homes and commercial buildings want to keep their initial selling costs down even though, over the lifetime of the building, the purchaser may well end up paying more through high energy usage for heating, cooling, and lighting. Likewise, industrial decisionmakers have been lukewarm to conservation and solar energy, insisting on twice as large a return (about 30 percent per year) from an investment in energy conservation as from an investment that increases productive output. [30]

Many conservation measures are relatively inexpensive and, even at today's fuel prices, would pay for themselves in energy savings in just a few months or years; as prices rise, they will become even more cost-effective. Many solar energy systems make economic sense today when compared with the cost of electricity, though not yet when compared with the cost of oil or gas. [31, 32] In all cases, these financial benefits accrue in the future through some substantial investment in the present. Consumers and businesses may prefer other ways of spending their money. Generally, an energy-related investment will not markedly improve current living conditions for the individual consumer or expand sales for the businessman.

In addition, it is characteristic of most CARE measures that they are purchased by the users of energy, rather than by the current producers of energy. Whereas a powerplant is purchased, constructed, and operated by an electric utility, a solar heating unit is purchased by the individual homeowner or builder for installation on the individual home. The user's return on this investment depends on the cost of the energy saved, and thus on the average cost of all facilities then producing and distributing energy. A supplier's investment choice, on the other hand, is based on the comparative cost of new facilities currently being built.

New energy production plants tend to be increasingly expensive so that, in general, an investment in conservation or solar energy would save more energy than would be produced by the same expenditure on new facilities using nonrenewable fuels. [4, 31] Cogeneration equipment costs industrial users more than what they are now paying for electricity, but less than what it would cost a utility to produce equivalent central powerplant capacity. [33] Since the user's investment is compared with the average cost of energy, while the supplier deals with replacement cost, the user's decision is weighted against the purchase. To overcome this, some alternative financing arrangement seems to be necessary.

One is to introduce some form of national subsidy, such as the recently approved tax credit for homeowners and businesses. However, this applies only to particular classes of taxpayers and will not address the general need for making CARE investments attractive to the energy user.

Another possibility would be to have the suppliers, especially the electric utilities, purchase (or loan the money for) conservation and solar installations. These investments would then be incorporated into the internal accounting of the energy producers. However, this would negate some of the main advantages of renewable energy systems, namely, their flexibility and amenability to control by the users. It would seem preferable to set up an alternative financing scheme which would accomplish the same end, that is, introducing a broad societal perspective into the financial arrangement, without transferring control to the current suppliers of energy. Since suppliers' investments will, in any case, be based on borrowed money which is repaid through payments by consumers, it should be possible, in principle, to devise mechanisms which would achieve this.

One would be an energy development bank which could borrow large sums at attractive rates on the private money market and loan these for CARE purchases, either directly or through local banking institutions, to users (including communities for shared, neighborhood-scale facilities). In effect, this federally backed bank would be borrowing the sums that would otherwise be drawn on by the utilities and other energy suppliers, and making them available to energy users. By loaning them out for long terms at low interest, the monthly cost to users can be reduced below what their energy spending would otherwise be. (Indeed, the San Diego Savings & Loan Association is already making available loans which are extensions of a homeowner's mortgage, so the homeowner may end up with no additional monthly cost for the CARE installation.)

With the introduction of a financing mechanism such as this, with a broad-based educational effort, and with the strong support of public officials, it should be possible to launch a national conservation and renewable energy program that would have the very great employment benefits identified in this study.

Part B. COMPUTATIONS

1. Methodology

In this study we estimate the impact on employment of the widespread introduction of energy conservation and solar energy measures, by envisioning a future in which there has been extensive investment in these sources and using economic projections to estimate the employment resulting from such spending.

For each conservation measure or solar energy application, estimates are made of its cost per unit energy saved or produced each year after the measure is introduced. A goal is set for the year 2000, by which time there will be specific levels of implementation achieved for each CARE measure. We assume that this goal will be achieved by a 5-year period of growth in CARE spending, after which there will be a fixed level of annual investment. The employment generated in 1990 by this investment is then determined from economic projections made by the Bureau of Labor Statistics of the U.S. Department of Labor. [16]

The BLS Projections

The BLS model gives estimates of the number of jobs involved in producing a dollar of output in each of 154 industries. These industries are obtained by aggregating the 476 separate industries identified in the Department of Commerce categorization of industrial sectors, and by creating some special categories for government enterprises, imports, and others.

The BLS modeling process begins with an estimate of the civilian labor force likely to be available in the year 1990. This is based upon Census Bureau projections of the overall population, BLS projections of labor force participation rates (the proportion of the working-age population that is working or seeking work), and an assumed rate of unemployment (BLS foresees the unemployment rate falling gradually from its 1977 level of 7.0 percent, reaching 4.5 percent in 1990). Projections are made of average labor productivity (dollar output per hour worked) and the average annual hours worked by each employed person. Multiplying the projected annual output per worker by the anticipated number of workers yields the potential gross national product which can be supplied by the available labor force using the then-current technology and working the then-average number of hours per year. At this stage, no assumptions about interest rates, investment flows, or other financial variables have been used. These are introduced through a macroeconomic model which allocates this supply GNP among the major demand categories of personal consumption, private investment, government purchases, and exports. These are further disaggregated into expenditures for each type of consumption or investment good or service, yielding the "demand" GNP.

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These projections are checked for consistency with projections of energy production and consumption. BLS uses energy projections prepared by Data Resources, Inc., to prepare a specific energy scenario which it uses for such comparisons. [11] This incorporates "business as usual" assumptions about the growth of demand for energy and increased production of nonrenewable fuels.

Input-output tables, whose coefficients have been projected forward, are then used to determine the output of each industry required to satisfy the final demand. From projections of the annual output of a worker in each industry, the number of jobs can be determined. (A "job" is defined through surveys of employers' payrolls; thus one person may hold more than one job, and a job may represent less than full-time employment.) The aggregate employment of all industries is then checked against the original assumed size of the labor force to assure consistency.

The input-output table is the central tool in estimating employment requirements. The coefficients in this table measure the output of each industry consumed by every other industry. Thus, they show the value of electricity utilized in the steel industry, the automobile industry, and all other industries (including electric utilities themselves), as well as the electricity sold directly to consumers. They also show the products purchased by each industry in order to produce a unit of its final output. The difference between the value of this final output and the cost of intermediate products purchased from other industries is the value added, composed of labor compensation, proprietors' income, profits, interest, indirect business taxes, and depreciation. (It should be emphasized that the input-output table is composed of exchanges among industries *within* the production process. The output which meets final demand is outside the table and is precisely equal to the total value added by all industries; that is, the total product equals the total income.)

As the composition of final demand evolves, and technology changes, the input-output coefficients will be modified. For instance, as industry increasingly emphasizes energy conservation, the coefficients describing purchases of energy from the coal mining, petroleum refining, electric and gas industries will decline; that is, less energy input will be needed per unit of output. (Since the value of energy consumed is generally a small fraction of the total value of output—usually less than 5 percent—other coefficients will not be greatly affected by this change.)

The jobs required to produce a unit of output from a particular industry are in that industry, in the industries which produce goods and services consumed by that industry, in the industries which produce goods and services consumed by those intermediate industries, and so on. To determine the total employment in all industries required to meet the demand for a particular industry's product, the "inverse" of the input-output table, or the total requirements table, is computed. The coefficients in this table show the total output required of each industry to meet a specified final demand. Multiplying each coefficient by the employment per unit of output in each industry (the "inverse" of its labor productivity) gives the total employment required in each industry to produce any final output.

The resulting employment factors include both the "direct" employment required in industries that produce a final product, and the "indirect" employment required in all supporting industries which provide material or service inputs into final producing industries. We will use the terms "direct" and "indirect" in a slightly different way than is conventional, to mean the production of all goods and services that are identifiable with the final product. Thus, for instance, "direct" employment in the solar industry will include not only those workers who assemble and install solar heating systems on consumers' homes, but also those who manufacture solar collectors and storage tanks. This enables us to maintain a clear distinction between jobs whose scale and organization will be most clearly affected by a change in demand, and jobs which will be less clearly attributable to a specific change in final demand. In the latter case, the goods or services produced meet a variety of different final demands, and the proportionate change in employment might be less than the fractional change in final demand, because of the industry's ability to absorb small changes without altering employment as much. Direct jobs tend also to be located in the local region where the demand is imposed, whereas indirect jobs will be more widely distributed across the Nation.

The following employment factors were used in this study:

BLS sector		Jobs per $1,000,000,000 of final demand (thousands)		
		Direct	Indirect	Total
11	Coal mining	20.46	8.13	28.59
15	New residential building construction	18.02	16.53	34.55
17	New public utility construction	23.76	14.79	38.55
21	Maintenance and repair construction	23.14	11.42	34.56
60	Petroleum refining	6.14	10.28	16.42
83	Engines, turbines, and generators	8.57	17.83	26.40
88	Special industry machines	12.80	15.44	28.24
89	General industrial machinery	14.80	15.61	30.41
93	Service industry machines	10.02	20.28	30.30
95	Electric industrial apparatus	16.82	15.58	32.40
96	Household appliances	8.03	20.64	28.67
101	Electronic components	17.08	16.08	33.16
117	Railroad transportation	11.69	9.66	21.35
119	Truck transportation	22.69	8.79	31.48
120	Water transportation	8.46	15.17	23.63
122	Pipeline transportation	4.21	10.11	14.32
126	Electric utilities	10.65	7.52	18.17
127	Gas utilities	8.14	10.47	18.61
129	Wholesale trade	23.66	10.10	33.76
130	Retail trade	52.62	6.03	58.65

Some Cautions

In estimating employment impacts, a number of conditions and qualifications must be kept in mind:

(1) The input-output method of projection provides us with a "snapshot" of the economy at a particular time, showing in what industries workers are employed and what they are producing. No experiments are performed to determine how a change in demand would affect employment. In this study, we are interested in incremental changes in employment associated with such a change in output, but an input-output analysis can give us only the ratio of the total employment in each industry to the output of that industry and industries to which it is linked, that is, the average employment per unit of output.

In using these average employment figures to simulate incremental effects, we are assuming that employment is proportional to output; that is, that there are constant returns to scale. The total employment in an industry, including the industries which supply goods and services to it, is assumed to be proportional to output. If there is a demand for increased output, or for a new type of product, the plant and equipment needed to produce these are assumed to increase in the same proportion as the labor force, and wage rates and other input costs are assumed to remain unchanged.

In general, we would not expect employment in an industry such as the energy industry to be proportional to output. The annual output of an electric powerplant or a refinery can change within fairly wide limits without much change in the number of workers in the plant, and the number of administrative personnel would vary hardly at all. In other industries as well, small changes in output can be accommodated without changing the number of workers, by altering the pace or organization of work. On the other hand, if large changes in output are required, so that the scale of plant and equipment is changed in proportion to output, we would expect employment to vary in the same way.

This is the situation we are projecting in this study, and we expect proportionality to be a reasonable approximation, especially for the direct employment which undergoes large changes as output varies. We may expect indirect employment to vary less, since a change in any one final product will have a lesser impact on intermediate suppliers, who may be expected to meet the small change in demand without too much alteration in employment.

In general, the BLS warning should be kept in mind:

> * * * manpower requirement factors should be considered as rough estimates of the relative labor requirements in a particular year for the various components of final demand and not as a measure of the actual jobs which would result from shifts in demand from one category to another.

(2) As we have seen, the use of BLS input-output tables to determine changes in the number of workers assumes a corresponding change in the plant and equipment used by these workers. However, the employment figures so obtained do not include workers in capital goods industries who produce that plant and equipment. Input-output tables include only what, in accounting terms, would be called "current accounts," that is, the direct inputs consumed in the production process—materials, components, fuels, spare parts, and repairs to equipment. Investment in plant and equipment is included in the value added to any output via its assumed depreciation.

New plant and equipment is produced as a part of the gross investment foreseen in BLS projections. The employment generated by such production can be computed by assuming a specific level of investment and determining the employment required for that output of capital goods. This is separate from the "current account" employment and requires additional assumptions as to the level of this investment.

Our projections do not include such investment. They assume that the conservation and solar energy industries are built up during the 1980's, so that by 1990 they have achieved a "steady state" level of output. In this scenario, the initial investment in plant and equipment takes place prior to 1990; from then on, there is simply replacement of these capital goods as they deteriorate or become obsolete.

In recent years, depreciation (or capital consumption allowance) has averaged about 10 percent of gross national product and about 15 percent of manufacturing output. Put another way, the mean life of manufacturing equipment is 5–10 years. Then the employment figures we obtain for the conservation and solar energy industries should be increased by 10–15 percent to take account of investment in depreciated plant and equipment.

(3) The BLS "snapshot" method does not describe the "multiplier effect," that is, the additional jobs created as newly employed workers (in, for instance, the solar energy industry) spend their added income on consumer goods and services. The input-output employment table describes average conditions, not incremental ones, and it does not tell us about such "ripple" effects. Studies generally suggest that there is an employment multiplier of about two; that is, one additional job is created by consumer spending for each job created in the initial production. However, this depends very much upon the type and location of the jobs created and upon overall economic conditions at the time. (In periods of high employment, there may be less additional employment than in slack times, there may be inflationary effects, and so on.) Such respending effects can only be determined with a full macroeconomic model.

In addition, the use of a multiplier assumes an injection of funds into the economy, over and above whatever initial level of investment and consumption is assumed. BLS projects a gross national product which already includes many new products and services not available today. It foresees a 30 percent increase in productivity between now and 1990, with per capita GNP rising from $9,871 to $13,225. This additional output will consist of many products whose nature is not specified in the BLS projections (though their distribution among major sectors is forecast). Conservation and solar energy goods and services may well be among the products that would be a part of this additional output, so that an unspecified portion of the flow of funds resulting from them may already be included in the BLS projection.

(4) In the BLS method (as in the Commerce Department's National Income and Product Accounts on which it is based), production precedes income. Wages and profits are viewed as the result of production, to be earned on the sale of products purchased with income received in a preceding period. The BLS method makes no assumption as to the source of the funds expended on output such as conservation materials and solar energy equipment. Individuals and corporations may purchase these out of current income, or they may borrow the funds from another individual, corporation, bank or agency. In the former case, their total spending on all goods and services will be unchanged; they will simply purchase less of some other products. In the latter case, total spending will be increased, but other investments might be affected. The net effect on employment, including these spending and investment shifts, cannot be determined without some additional assumptions as to the source of funds and the use of a complex macroeconomic model.

To summarize, the employment figures we obtain as a result of conservation and solar-related investments will reflect average employment and may somewhat overestimate indirect employment; they will not include employment generated by the need to invest in new plant and equipment; they will include only workers employed in CARE industries and industries which supply them, not workers employed as a result of the spending of income generated in the CARE industry; and they will not give the net jobs created or displaced as a result of the overall change in spending induced by expenditures on CARE goods and services.

Further Assumptions

A number of additional assumptions and methods are used in making our estimates of CARE-related employment:

(1) We have used current estimates of the cost of conservation and solar equipment, decreasing this cost somewhat in those cases where it appears that mass production will cut costs. Should the cost fall dramatically as a result of some not-now-foreseen innovations, the same total investment, and the same number of workers, could produce and install more units and hasten the day when full "solarization" was a reality.

(2) Only presently available or clearly achievable technologies are included. Thus, the extraction of energy from the ocean is not considered, since no demonstrated technology now exists which seems likely to permit sizable energy production from the ocean during the next decade.

(3) Representative aggregated industries in the BLS model are used to simulate particular conservation and solar energy industries. Some preliminary studies have been made of the material and labor requirements of a solar industry, but these apply only to a few particular technologies and current production technologies. [34, 35, 36] Undoubtedly, both the technology and production techniques will change as additional experience is gained and output is substantially increased. Furthermore, the employment/output ratios in the BLS model apply only to aggregated industries and are expected to be only rough approximations to the actual state of affairs in 1990. Thus, the approximation of CARE industry and employment distributions by suitable, already-existing "surrogate" industries from the BLS sectoral framework seems commensurate with the accuracy of the BLS projections. In each case, industries are chosen which seem most closely to simulate the types of activities involved in the production and installation of the particular technology.

(4) In the BLS tables, final demand is valued at the production site, in "producers' values." To obtain the value at the site of purchase, transportation and wholesale and retail charges or margins must be added. These are approximated by using the margins as determined by the Department of Commerce in its detailed survey of the U.S. economy in 1967, which is the basis of the BLS input-output tables. [37]

(5) Energy is measured in millions of British thermal units (MMBtu=10^6 Btu) and quads (1 quadrillion Btu=10^{15} Btu). One MMBtu is approximately equal to the energy supplied by 7.2 gallons of crude oil, 84 pounds of bituminous coal, 980 cubic feet of natural gas,

or 293 kilowatt-hours of electricity. Some other useful ways of expressing this equivalence are: 1 MMBtu per year=0.0334 kilowatt=4.73×10^{-4} barrel of oil per day, and $1 per MMBtu per year=$29.94 per kilowatt=$2,114 per barrel per day. Currently, fuel oil costs about $4 per MMBtu, natural gas about $1.70 per MMBtu, and electricity about $6–12 per MMBtu.

In 1977 the United States consumed about 75.9 quads of primary energy, or 59.6 quads of end-use energy. The difference is in the way electrical energy is counted; about 3.4 Btu of primary fuel is required, on the average, to produce 1 Btu of electricity at the site of end-use.

(6) 1978 dollars are used throughout this study.

In this study we assume specific implementation goals in each area of CARE technology and use. Readers interested in determining the impact of alternative goals can do so easily. In this approach the number of jobs is directly proportional to the dollars invested in each category, and the investment is proportional to the energy-saving objective.

2. Residential Use

The most cost-effective action one can take to reduce fuel consumption in the home is to reduce the unnecessary loss of heat through the housing "envelope." This is, then, the first step in any conservation program. One can go beyond this, however, to make the home a more effective absorber of the Sun's energy, both by changing the design of the home so that it admits more sunlight and stores the energy received in this way ("passive" solar design), and by using a moving fluid (water, air, ethylene glycol) which is heated outside the home and then brought inside to give off its energy ("active" solar energy). Studies are beginning to show that the combination of these techniques, including particularly a serious attempt to reduce heat loss, can go so far as to eliminate all dependence on outside fuel sources for heating and cooling. [4]

Conservation

The energy conservation measures that can be applied to a home include adding insulation to the walls and ceiling, insulating attics and basements to avoid heating unused areas, adding storm doors and windows, adding shutters, caulking to reduce heat loss through window frames and other cracks in the housing envelope, and using a thermostat that shuts down any heat source in the evening and whenever no one is in the home. Waste heat can be recovered from heater flues and from hot water before it drains off into the sewer system.

Dramatic reductions in fuel consumption can be achieved by such measures. Studies performed even on 1970-vintage, reasonably well-insulated homes are showing that fuel consumption can be reduced more than two-thirds by such measures. [38] Existing Federal standards for home retrofitting would reduce fuel consumption by 35 percent; for new homes, they would reduce it 50 percent. [39] Thus a 50 percent reduction in fuel consumption for home heating by conservation measures alone seems a reasonable objective to be achieved by the year 2000. This would require an expenditure of between $250 and $2,000 per residential unit. [39, 14, 40, 41]

The cost of these measures per unit of energy saved depends to a large extent upon the initial condition of the house. The first measure applied to a "leaky" house may cost little and achieve a great deal. As the home is made progressively "tighter," or if it is a new home that is already well insulated, the cost of reducing energy consumption is greater. The following figures characterize these different situations [39, 19, 4, 42, 43, 44]:

	Dollars per MMBtu per year saved
Initial measures on a poorly insulated house	5
Further measures on a poorly insulated house, and initial measures on a well-insulated house	20
Further measures on a well-insulated house	50

Energy consumption in the home can also be reduced by making other appliances—the refrigerator, stove, hot water heater, lighting—more efficient converters of energy into the qualities—cooling, heat, light—we want from them. It appears possible, by careful redesign, to make appliances that use 50 percent of the energy that present models consume, at costs in the range $5—15 per MMBtu per year saved. [39, 22, 45]

Passive Solar

New homes can be designed in such a way that they let in a maximum amount of sunlight in the winter, with this solar energy being absorbed and stored in stone, brick, or water for nighttime and cloudy-day heating. Overhangs or sunscreens can be used to shade the interior in the summer. In existing homes, absorbing elements can be placed within the home and, in some cases, windows can be added. The effectiveness and cost of such measures clearly depends very much on the design and placement of the home. From 40 percent to as much as 90 percent of the heating energy needed for a home can be provided in this way, at a cost that ranges from $5 to $150 per MMBtu per year. [4, 46, 47, 48]

Active Solar

The active solar technology which is most likely to be implemented on a large scale in the coming decade is the flat-plate collector coupled to home heating and hot water systems. Air or water is heated in the collector and piped into the home. The heat is then either transmitted directly to the heating and water system or stored for later use in the evening or on cloudy days. The "technology" involved in conventional plumbing hardware with collectors having a variety of relatively simple designs.

More advanced technologies are in various stages of development and will probably play an important role in the 50-year solar transition that we foresee, though they are unlikely to be widely installed in the short term. These include various systems for combining the production of electricity, using photovoltaic cells, with the collection of heat (see Section 7 of this Part), and heat engines which can convert solar energy into mechanical and electrical energy to power electrical appliances, heat pumps, and air conditioners, as well as provide heat for home heating and hot water. [35] Such systems are highly efficient (in the sense that they convert a large portion of the solar energy into useful activity), but they are relatively expensive at the present time and seem unlikely to achieve wide acceptance in the near future.

According to the conventional wisdom, ordinary solar heating and hot water systems can provide, at best, 50–80 percent of the heat requirements of the average home. They need to be backed up with oil-, gas- or electricity-powered systems for unusually cold or cloudy periods. However, experience with solar-heated homes and detailed analysis [4, 46] are beginning to suggest that, if higher insulation standards are applied to homes (as suggested above), solar units of reasonable cost will be able to provide 100 percent of the heat requirements of the average home. This may involve somewhat larger storage tanks than are assumed in most analyses [for instance, 35], and it can be facilitated by the sharing of storage tanks among as many as 10 to 100 housing units, thus substantially reducing the storage cost.

In spite of the increasingly apparent ability of solar energy to meet all of the heat requirements of the average home, it seems likely that, for the near term, most people will want to have some kind of backup system. Gradually, we would expect that confidence in solar systems will develop, but most new homes will still incorporate conventional systems as well. These cost on the order of $1,000 for a heating system, a small fraction of the total cost of new homes today.

We also expect that, in the near term, solar cooling systems will not be installed as part of most solar energy systems. Since the same solar collectors that provide heat in the winter can supply energy to operate an air-conditioning system in the summer, their overall efficiency can be increased by adding a cooling system and using them year-round. However, the added cost and complexity of air conditioning will probably lead most people to postpone installing such a system which, in any case, can be added later as rising electricity costs make it increasingly desirable. (The extra costs are of the order of $3,000 per housing unit.) [35]

Thus, we assume, for the short term, widespread introduction of solar heating and hot water systems using flat-plate collectors, with incorporation of the more complex and expensive systems postponed until later.

Commercially installed collectors today cost $7–$30 per square foot. Of this, about one-half is the purchase price of the collector, the rest is materials and labor for installation. These costs are expected to drop about 30 percent with the onset of mass production, to $5–$20 per square foot. [49, 35, 4]

The remainder of the system, including pumps, controls, and storage sufficient for 5–10 days, adds another 25 percent to the cost of the system (Pumps and controls add about $1 per square foot, or $500 per housing unit; storage costs $1–$3 per cubic foot, and about 1–1.5 cubic feet per square foot of collector is required.) [35, 4] Thus the total system cost is $8–$40 per square foot today and is expected to drop to $7–$25 per square foot with expanded production. The cost for multifamily housing units should be as much as 50 percent less because of the sharing of controls, storage, etc. [49, 35, 4]

The solar energy falling on a collector varies with the location of the site (generally decreasing with increasing latitude) and the average weather at the site. For an average location in the United States, the mean "insolation" is about 0.60 MMBtu per year per square foot. We are assuming that the solar system is being used only for home heating and hot water, not for air conditioning, and only about one-third of this energy is available in the winter, when it is needed. (It should be noted that concepts of seasonal storage, involving large shared tanks or ponds with 6-month storage times, are being developed [35], but these are not likely to be installed in very great numbers within the time frame under consideration here.) Hot water, of course, is needed year-round, but it accounts for only about one-fourth of the total energy demand placed on the system.

Collectors are able to absorb and send into the home about one-half the solar energy incident on them. Thus, the effective energy conveyed by a collector is, on the average, 0.10 MMBtu per year per square foot. [49, 31, 35, 36] The cost of energy supplied by a solar heater is then expected to be $70–$250 per MMBtu per year.

Energy Savings

To summarize, the cost of residential energy measures is:

TABLE B-1

	Dollars per MMBtu per year
Conservation measures:	
Building	5–50
Appliances	5–15
Passive solar	5–150
Active solar	70–250

The average energy use per housing unit during 1977 was 150 MMBtu.[1] Of this, about two-thirds, or 100 MMBtu, was used for heating and hot water; the remaining 50 MMBtu were used to power various appliances and for cooking. [50, 51, 39, 52] (Multifamily units, which compose about 30 percent of all housing units, use about one-half as much energy as single-family homes; these figures are composite averages.)

If our energy conservation goal of 50 percent, for both building and applicances, is achieved, there would be a saving of 75 MMBtu for our average house. Assuming that 20 percent of the remaining heating load is met by some type of passive solar measure, the active solar system must provide 40 MMBtu in order to meet the full heating and hot water load of the home, and external sources (primarily electricity) must provide 25 MMBtu to power the various appliances in the home. The cost of CARE measures, per housing unit, may be estimated as follows, using costs per unit of energy roughly intermediate within the ranges shown in Table B-1:

TABLE B-2

	Energy saving (MMBtu per year)	Cost (dollars)
Conservation measures:		
Building	50	[1] 1,000
Appliances	25	250
Passive solar	10	200
Active solar	40	4,000
Total	125	5,450

[1] This is an average for new and existing housing and single and multifamily dwellings.

[1] This is measured in terms of end use energy, at the residence. Because of the losses incurred in the production and distribution of electricity, fuel consumption per house was 221 MMBtu.

The overall fuel usage by this average home has been reduced to 25 MMBtu per year, one-sixth of its original value. This estimate takes into account the expected growth, in the absence of solar measures, of the share of homes that are electrically heated.

Employment

Having determined the cost of reducing the fuel consumption of the average housing unit by more than 80 percent, we can now estimate the employment produced by such an effort, using the BLS projections. As explained earlier, we will use the average employment rates per dollar of final demand in "surrogate" industries to estimate the effects of energy conservation and solar installation:

For building conservation measures in existing homes, we use Maintenance and Repair Construction (BLS Sector 21). This sector involves the same type of construction labor as do most building conservation measures, and the share of total spending used to purchase materials (64 percent in the BLS projection) is comparable with the 50–65 percent expected with conservation retrofitting. [53, 41, 48] For new homes, we use New Residential Building Construction (BLS Sector 15).

For appliance conservation, which takes place largely during the manufacture of appliances, we use Household Appliances (BLS Sector 96), taking into account average sellers' markups and transportation costs that are 34 percent of the selling price and the jobs thus created in the Truck Transportation, Wholesale, and Retail Trade sectors. [37]

For passive solar, we use Maintenance and Repair Construction for existing homes and New Residential Building Construction for new housing units.

For active solar, we use New Residential Building Construction. This sector involves the same type of products as the solar industry (except that it uses more wood products), and it has the same share of spending on materials and components (65 percent) as studies find to be true of the current solar energy industry. [34]

Using Table B–2 and the BLS projections, we then find the following employment impact per housing unit:

TABLE B–3

	Job per housing unit		
	Direct	Indirect	Total
Conservation measures:			
Building	0.022	0.013	0.035
Appliances	.005	.004	.009
Passive solar	.004	.003	.007
Active Solar	.072	.066	.140

Using the BLS projection of an average of 1,832 hours worked per year per employee in the nonfarm private sector, this can be expressed in terms of hours worked:

TABLE B-4

	Hours worked per housing unit			Total hours per MMBtu per yr.
	Direct	Indirect	Total	
Conservation measures:				
Building	40	14	64	1.3
Appliances	8	7	15	.6
Passive solar	7	5	12	1.2
Active solar	132	121	253	6.3

National Projection

To project the national impact of a residential energy conservation and solar energy program, we need to make an assumption as to the rate at which these measures are implemented in the coming years. We will assume that the programs build up between 1980 and 1985 and, thereafter, remain at a constant level of investment to the year 2000 when they will have reached the following goals:

TABLE B-5

	Percentage of implementation by 2000
Conservation measures:	
Building	100.
Appliance	100.[1]
Passive solar	100 (new homes); 50 (existing homes).
Active solar	100 (new homes); 50 (existing homes).

[1] Note that the mean lifetime of a household appliance is about 15 years. Thus, in the 15 years between 1985 and 2000, each home would, on the average, have purchased one of each type of appliance meeting the new, higher energy efficiency standards projected here.

In 1976 there were 72 million household units. These are projected to grow to 99 million in 1990 and 114 million in the year 2000. [39] Using Tables B-2, B-3, and B-5, we find the following total annual investment and number of jobs in 1990:

TABLE B-6

	Annual investment (billions)	Number of jobs (thousands)		
		Direct	Indirect	Total
Conservation measures:				
Building	$5.7	125	74	199
Appliances	1.4	29	23	52
Passive solar	.7	15	11	26
Active solar	14.8	266	244	510
Total	22.6	435	352	787

For comparison, BLS projects total investment in new residential construction in 1990 as $108 billion, with a total work force in that industry of 1,564,000. Thus the conservation and solar industry projected here gives a 20 percent boost to that industry and those that provide it with materials and equipment.

We can also estimate the total energy savings in 1990 and 2000, as well as the savings in fuel (recognizing that 3.4 Btu of fuel are required to produce and deliver 1 Btu of electrical energy from conventional power plants). By 1990, 54 million homes would have passive and active solar; by 2000, these figures would be 114 million and 75 million, respectively. The energy and fuel savings are:

TABLE B-7

	Energy saved (quads per year)	
	1990	2000
Conservation measures:		
Building	2.7	5.7
Appliances	1.4	2.9
Passive solar	.3	.7
Active solar	1.4	3.0
Total	5.8	12.3
Fuel saved	10.0	23.0

Once installed, these measures are relatively maintenance-free. Solar heating systems, though, will occasionally break down and need some repair. If we assume an average of 2 worker-hours per year per home for maintenance of the solar energy systems, there will be about 40,000 jobs in 1990 in this activity.

3. Commercial Use

The commercial sector, including nonresidential buildings (other than industrial plants) such as office buildings, retail stores, schools, hospitals, etc., consumed about 5.5 quads in 1977 and is expected to use about 8.4 quads in 1990. Of this, about 30 percent is currently in the form of electricity; this share is expected to rise to about 37 percent by 1990. [54, 44, 55]

Substantial energy savings are possible in the commercial sector. Not only are there the usual inefficiencies in our economy due to lack of attention to energy conservation in equipment and building design, but recently constructed buildings are especially wasteful of energy. Air conditioning is often used in modern office buildings to remove the heat generated by lights and people, and the widespread use of glass increases the cooling load in summer and the heating load in water. [56, 19]

Conservation

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) has issued standards for energy conservation in new buildings which, if conscientiously applied, would reduce energy consumption in office buildings by 60 percent and in retail stores by 40 percent. [57] Federal Executive Order 12003, issued July 20, 1977, has already established a goal for 1985 of 45 percent less energy usage in new Federal buildings and 20 percent less in existing structures. Thus, setting a goal of a 50 percent reduction in energy use in all commercial buildings by 2000 seems reasonable.

Solar

Heating and hot water demand, which now accounts for about two-thirds of commercial energy use, would be reduced an average of 42 percent by application of the ASHRAE standards. Application of somewhat tighter standards, looking toward a 50 percent reduction in this specific area of energy use, by the year 2000 is then a reasonable goal. Much of the remaining demand could then be met by solar heating systems. As solar air conditioners become readily available, these could be added to the solar systems, but we will assume that this takes place later than the period under consideration here. Having looked toward stringent energy conservation measures, we can now assume that the remaining heating and hot water needs, amounting to one-third of current energy use, can be taken over by solar energy systems.

Projection

The application of energy conservation measures to new commercial buildings will probably involve no net additional cost, since smaller, less costly heating and cooling systems can then be installed. An assessment of the ASHRAE standards suggests that the savings in equipment approximately compensate for the added cost of insulation and efficiency improvements. [57] For existing buildings, on the other hand, we may expect conservation measures to cost approximately what they do on residential buildings. [14] Solar units, on the other hand, will cost about one-half what they cost for single-family residences, per Btu saved.

Setting a goal of 100 percent of all buildings to have conservation measures applied by the year 2000 and 50 percent to have active solar heating and hot water systems installed (passive solar measures may be considered with other energy conservation steps), we find the following investment, employment, and energy savings:

TABLE B-8

	Annual investment (billions)	Number of jobs (thousands)			Energy saved (quads per year)	
		Direct	Indirect	Total	1990	2000
Conservation measures	$2.4	52	34	86	2.5	5.2
Solar systems	6.6	119	109	228	2.2	3.5
Total	9.0	171	143	314	4.7	8.7
Fuel saved					8.0	16.0

Here we have used the same projections for employment requirements per dollar of demand as in the residential case and have averaged the conservation measures, assuming two-thirds of the conservation effort is in building factors and one-third in equipment efficiency improvement.

4. Industrial Use

In 1977 industry used 21.3 quads, nearly 40 percent of all end-use energy. About 12 percent of this was in the form of electricity and another 14 percent was natural gas and petroleum used as feedstocks. [11] About 70 percent of industrial energy use is for process heat in the form of hot water, steam, and hot air or direct heat. [14, 58]

Industry, in seeking to control its costs, has always practiced some form of energy conservation. This is especially true of those particular industries (primary metals, chemicals, paper, and petroleum refining) which are most energy-intensive. Nevertheless, significant opportunities for further conservation measures exist, and solar energy can also contribute to reducing fuel consumption by industry. As Hatsopoulos et al. point out, industry has used investment criteria for conservation decisions which have ruled out measures which are actually cost-effective. [30]

Conservation

Most forecasts look toward a continuing growth in energy consumption by industry, but also an increasing efficiency in its use of energy. The BLS and DRI projections envision an absolute rise in industrial energy consumption of 3.1 percent per year, but at the same time they foresee a decline of 1.1 percent per year in the ratio of energy consumption by industry to total manufacturing output. [11] By 1990, this will have produced a 13 percent decline in the energy-to-output ratio. Several studies have concluded that savings of 30–40 percent are possible if careful attention is paid to the organization and operation of industrial processes (better "housekeeping"), if waste heat is captured and recycled or used for producing electricity, if high efficiency electric motors are introduced, and if the use of recycled materials is increased. [19, 59, 60, 46] The additional energy savings will generally involve some investment of capital and will therefore produce employment. Estimates of the cost of energy conservation measures, from heat recuperation to more efficient electric motors to process modifications, are in the range $0.80–$5.00 per MMBtu per year. [30]

Cogeneration

The cogeneration of electricity with the production of heat is the most interesting of these, since it offers a way of reducing the industrial demand for electricity from central station powerplants that produce only 1 Btu of electricity for every 3.4 Btu of nonrenewable fuel they consume. In cogeneration, high temperature steam is allowed to expand through a turbine to produce electricity before being exhausted at low pressures for use as process steam, or lower temperature waste heat from cement kilns and other high-temperature devices is used to make electricity. The additional fuel needed to produce electricity in this way (beyond that needed to make heat or steam in the absence of the electric generator) is only about 60 percent of that required to produce and deliver equivalent electricity by a central power station, namely, 6,000 Btu per kilowatt-hour of electricity, compared with 11,500 Btu per kwh at a powerplant. Actual on-site fuel consumption is higher than it would be without cogeneration (amounting to 1.8 Btu per Btu of electricity produced), but less fuel is used than would be consumed by central generation, saving 1.6 Btu per Btu of electricity produced. [33]

Today there is the central station equivalent of about 15,000 megawatts of cogenerating capacity in existence. [61] It has been estimated that about 50 percent of all process steam production is suitable for cogeneration and that there is the potential for efficiently cogenerating electricity equivalent to 193,000 megawatts of central station capacity at the present time. Operating 90 percent of the time, such generators would produce 3.4 quads per year of electricity. [33] Cogeneration equipment costs (for the additional electric-generating capacity) are in the range $8–$30 per MMBtu per year in equivalent electricity. [33, 4, 62, 30, 63]

Solar

Solar energy may be used to supply the heat and process steam needed in many industrial applications. Only for the very highest temperatures (above 1000° F or so) does it become difficult to use solar-collected heat (though even here solar-generated electricity can be used in electric furnaces to attain these temperatures). [35, 46] Some cost estimates of solar systems are:

	Dollars per MMBtu per year
High-temperature focusing collector [35, 64]	30–70
Heliostat (power tower) [46, 64]	15–80
Rankine engine [35, 4]	15–30

Since industrial heat processes are about 80 percent efficient, each Btu produced by solar means will replace 1/.8=1.25 Btu of fuel.

Projection

We set the following goals for industrial energy use:

An additional 20 percent reduction in energy consumption by 1990 through process improvements, recuperation, and the installation of more efficient motors and other equipment.

100 percent use of all cost-efficient cogeneration sites by 2000.

25 percent of all industrial process heat to be supplied by solar energy by 2000.

To determine the impact of such goals, we use the DRI projection of 31.9 quads of industrial energy consumption, including 6.6 quads of electricity, in 1990. [11] We also assume that the potential for cogeneration grows in proportion to manufacturing employment, and that process heat requirements grow in proportion to manufacturing output. As before, we assume that programs build up between 1980 and 1985 and remain at a constant level of investment thereafter.

To estimate employment, we use an average of the sectors involved in producing industrial equipment. This seems appropriate for industrial conservation gear, and solar equipment suitable for industrial application is likely to be more complex and refined than the simpler gear to be installed on homes and commercial buildings. Thus we use an average composed of the following sectors: Engines, Turbines, and Generators (BLS Sector 83); Special Industry Machines (BLS Sector 88); General Industrial Machinery (BLS Sector 89); Service Industry Machines (BLS Sector 93); Electrical Industrial Apparatus (BLS Sector 95); and include Truck Transportation and Wholesale Trade (BLS Sector 119, 129) margins.

We then find the following:

TABLE B-9

	Annual investment (billions)	Number of jobs (thousands)			Energy saved (quads per year)	
		Direct	Indirect	Total	1990	2000
Conservation measures	$1.5	20	25	45	6.4	8.6
Cogeneration	3.8	51	62	113	1.8	3.8
Solar systems	12.1	163	198	361	4.3	9.5
Total	17.4	234	285	519	8.9	14.3
Fuel saved					19.0	34.0

There will be a need to maintain and repair cogeneration and solar equipment. It has been estimated that the annual cost of operating and maintaining such equipment is about 1 percent of its capital cost. [65] In 1990 this is about $1.4 billion. Using BLS Sector 21, Maintenance and Repair Construction, to estimate the resulting employment, we find 48,400 total jobs, and 32,400 direct jobs.

5. Transportation

Transportation energy use is one of the most important areas to address when attempting to reduce the consumption of nonrenewable fuels, and yet it is also one of the most difficult. Both its importance and its difficulty reflect the overwhelming predominance of the automobile (and, secondarily, the truck) in American transportation today. The private automobile consumes enormous amounts of increasingly scarce fuel, but its presence has helped to shape residential and commercial land use patterns that make it difficult to avoid relying on the auto for personal transportation. Only on a time scale of 50 years or more, the typical turnover time for residential housing, is it possible to envision any truly substantial change in tronsportation patterns. Nevertheless, some steps can be taken now, and it is important to begin now if the 50-year transition is to occur while gasoline supplies are still relatively plentiful.

Transportation accounted for 56 percent of the 34 quads of petroleum used in 1977. Further, the refining of petroleum consumes about 0.12 Btu for every Btu of usable fuel produced (this consumption appears in the industrial sector in the energy accounts), so that transportation actually claimed 63 percent of all petroleum consumption. [11, 14]

The major users of transportation fuel are automobiles (47 percent), trucks (22 percent), ships (15 percent) and aircraft (7 percent). Buses account for less than 1 percent, and railroads (carrying primarily freight) for only 3 percent. [66] The most inefficient use of automobiles, of course, is in urban areas, especially for commuting, where the single person driving to work alone in a 2-ton automobile has become almost a symbol of America's energy wastefulness. Studies of urban transportation have shown that, on the average, buses use 43 percent as much energy per passenger-mile as autos, while rail systems use only 29 percent as much.[2] [28] Nevertheless, mass transit continues to account for only about 2.5 percent of all urban passenger travel. [67]

[2] Interestingly, because of low average load factors in some experimental operations, the once-attractive Dial-a-Bus idea now seems less appealing; it uses 15 percent more energy per passenger-mile than the private automobile.

Technological Changes

The automobile consumes the most fuel and offers the greatest opportunities for conservation. Seeking improved automotive efficiency is the first step that has been taken, and that can still be taken, to curb petroleum consumption. The Energy Policy and Conservation Act of 1975 mandated an average 1985 new car auto mileage of 27.5 miles per gallon, a substantial improvement on the 1976 new-car fleet average of 17.1 miles per gallon. Further improvements are possible, with the limit dependent more on the tastes of the American consumer (and the way these are influenced by auto industry advertising) than on technology. Volkswagen has recently introduced a supercharged diesel-powered Rabbit which gets 60 miles per gallon, so there is a long way to go.

Fuel efficiency can be improved by engine design improvements, better matching of the engine to the auto load, reduced drag through body design changes and use of radial tires, and reducing the weight of the automobile. Diesel engines, which use 30 percent less fuel, may be introduced on a wide scale, if their associated particulate pollution can be reduced. It seems reasonable to seek a 40 mile per gallon new-car average for 2000, with these gains to be achieved primarily through weight reductions. If this were done, and if auto miles driven rises in proportion to the adult population [17] automotive fuel consumption would decline to 5.4 quads in 1990 and to 4.5 quads, half its current value, in 2000.

It does not appear that this will have a very significant effect on employment, except among those engaged in research on efficiency improvements and in changing over auto production lines. Less steel is likely to be used, but steel input is only about 7 percent of the value of auto output, and one study found little net change due to the replacement of steel by plastic. [41] Another study concluded that the nonfuel cost of automobiles getting up to 40 miles per gallon is "remarkably insensitive" to gas mileage, suggesting again little job impact. [23]

Petroleum may also be saved by using electrically powered vehicles, especially for intraurban travel, with the electricity supplied now by coal- or nuclear-fired powerplants but, eventually, by direct or indirect solar energy. Already there are battery-powered autos and minibuses being operated successfully on an experimental basis, and this seems a promising approach to pursue. However, because solar-generated electricity will not be widely available by 1990, this will not be a significant part of our projected "solar economy" in that time frame.

Modal Shifts

Encouraging the shift from use of the energy-inefficient auto and airplane to use of buses, subways, trolleys, and trains is an obvious step toward energy conservation. However, it is difficult to achieve much energy saving this way, at least in the short run. For instance, less than 3 percent of urban passenger travel today uses mass transit, so even a doubling in the number of people who ride the buses and subways will hardly make a dent in automobile travel. In fact, Hirst has estimated that such a doubling would save only 0.1 quad per year. [67] Existing mass transit systems cost about $4 billion each year. Doubling their size and, presumably, their ridership would involve adding this much operating expense, plus an investment of at least twice this much in equipment, rail-bed, repair facilities, etc., while saving about $0.5 billion in gasoline purchases. Converting this into the terms we have been using previously, and treating operating expenses as being equivalent to an investment paying 10 percent annual interest, mass transit costs $500 per MMBtu per year saved. This is much greater than the cost of other types of energy-saving investments we have examined. In addition, unlike other measures we have discussed, it requires a change in everyday behavior—riding mass transit to work—if the energy savings are to be realized, and it would continue the consumption of nonrenewable fuels.

Some degree of modal shift can be accomplished without any additional investment, as individuals are encouraged to change to more energy-efficient modes of travel. Quantitatively, this will show up as an increase in the load factor (the average number of passengers) riding buses and trains and as an increased load factor for automobiles, as carpooling to work is encouraged. This is, in fact, the least-costly way of reducing urban auto travel, and it could have significant effects; increasing the number of cars carrying two people from an average of 1 out of 5 to 2 out of 3 could save nearly 1 quad.

Projection

The DRI projections foresee, as a result of rises in the price of oil, a decline in gasoline consumption of 5 quads between 1977 and 1990. This is consistent with the effects of improvements in automotive efficiency and shifts to mass transit we have discussed. As to employment impacts, the former, while effective in reducing gasoline consumption, opens up few employment opportunities. The latter, while potentially a large job-producer (through the manufacture and installation of mass transit systems and the operation of such systems), will not produce enough energy savings to be justified on these grounds alone. Thus we do not project any specifically energy-related employment impacts related to conservation measures in the transportation field.

In the long run, shifts to mass transit can induce a trend toward higher density construction, which will lead both to more energy-efficient housing and to additional use of mass transit instead of private automobiles. Studies suggest that high-density planned communities can enable the construction of more energy-efficient housing, make solar energy installations more feasible and more efficient, and greatly reduce transportation costs. Energy savings of over 60 percent have been estimated. [28, 68, 69, 29] Thus, though investment in mass transit cannot be justified on short-term energy conservation grounds alone, it does appear to be an intrinsic part of any long-run energy-conserving strategy. [70]

6. Portable Fuels

Organic waste matter, or biomass, represents an important energy source for the future. Agricultural wastes, as well as sewage and other urban wastes, contain stored-up solar energy—just as does petroleum, the end product of a once-living, energy-storing plant. These wastes can be burned to produce heat and electricity, but they will be far more valuable in the future as sources of liquid and gaseous fuels. There are other, equally efficient ways of using solar energy to yield heat and electricity, but there is no other readily available source for the portable liquid and gaseous fuels needed for transportation.

Biological material can be processed to yield methane, the combustible ingredient in natural gas, and two forms of alcohol, ethyl alcohol (ethanol or grain alcohol) and methyl alcohol (methanol or wood alcohol). Our current transportation system would require little modification to use these solar-generated fuels. Already, gasoline mixed with 10 percent alcohol is being used in the Midwest, and Brazil is now producing ethanol (at 2–3 times the U.S. price of gasoline) for automobiles. [4]

An acre of grain (30 bushels) could produce 15,000 cubic feet (16 MMBtu) of methane or 85 gallons (8 MMBtu) of ethyl alcohol per year. An acre of corn could produce twice this; sugar beets could produce even more. [71] (Note that, per gallon, ethanol and methanol have 76 and 54 percent, respectively, of the energy content of gasoline.)

The energy content of the 1,600 million tons per year of current waste products (crop residues, animal feedlot manure, and urban waste) is about 8 quads. This is expected to rise to 16 quads by the year 2000. About one-half of this is recoverable in the form of methane or alcohol, because of losses and fuel usage in the conversion process. [72, 73] Waste products yield about 3,500 Btu per pound, about one-third the energy value of coal.

Biogas plants using anerobic fermentation to produce methane, or pyrolysis to yield a low-Btu gas, cost $10–25 per MMBtu per year. [4, 74] Plants producing alcohol cost $15–$35 per MMBtu per year output.[3] [40, 75]

Setting as a goal the conversion of one-half of all agricultural and urban waste products to methane or alcohol by the year 2000, we find the following:

TABLE B–10

Annual investment (billions of dollars)	4.3
Number of jobs:	
Direct	89,000
Indirect	77,000
Total	166,000
Energy saved (quads per year):	
1990	1.8
2000	4.0

We have determined the employment impact using BLS Sector 17, New Public Utility Construction.

Waste processing plants require about 30 employees per trillion Btu's per year output. [74] Using the BLS estimate of 1.83 for the average ratio of indirect to direct jobs in Electric Utilities (BLS Sec-

[3] Another potential source of portable energy is hydrogen, which can be produced from water using electricity or high temperatures. It has been estimated that hydrogen production using solar thermal receivers (power towers) would require an investment of $22 per MMBtu per year. [76]

tor 126) and Water and Sanitary Services (BLS Sector 128), this yields for 1990 about 54,000 direct jobs and 97,000 total jobs in operating these plants.

7. Electricity

There are a variety of ways of producing electricity using energy from the Sun. With active stimulation of the market via Federal policy, and financial measures that can overcome some of the institutional barriers, these could make a substantial contribution to the Nation's energy needs by the end of this century.

Photovoltaics

Photo-sensitive semiconductors have been used for several decades to provide usable amounts of electricity, especially for applications in outer space and rural areas. Production volume has been low and costs high, so they have not been able to provide electricity at a price comparable with that produced in conventional fossil fuel- or nuclear-fired powerplants. However, production is beginning to expand, active research and development are underway, and prices appear to be falling rapidly.

Solar cells cost $2,000 per peak watt in the late fifties. By the end of 1977 they could be purchased for as little as $6 per watt. [31] Electricity from such systems would cost about $1 per kWh, still about 25 times the cost of conventionally produced electricity.

Department of Energy goals call for the achievement of photovoltaic array prices of $1–$2 per peak watt in 1980, of 50 cents per peak watt in 1986, and of 10–30 cents per peak watt in 1990, at which point there would be annual sales of 50,000 peak megawatts of capacity. At this rate solar electricity would be contributing more than 20 percent of the annual additions to electric generating capacity foreseen in the usual projections. [77] The Congressional Office of Technology Assessment has found these goals "optimistic but not impossible," while noting that "achievement of costs below $1–$2 per watt will require a considerable amount of engineering development work." [35]

Assuming that these goals are met, and that photovoltaic arrays reach an average of 20 cents per peak watt, an installed collector system will cost 30–75 cents per peak watt, or $2–$5 per square foot. [35] Since cell conversion efficiencies are about 10 percent, and the average "insolation" in the United States is about 0.60 MMBtu per year per square foot, such a system will cost $30–$80 per MMBtu per year (or, equivalently, 10–27 cents per kWh per year).

In such a system the photovoltaic cells account for as much as two-thirds of the cost. An alternative design, which can use fewer, more expensive, and more efficient cells, uses an optical concentrator that tracks the sunlight and focuses it upon the cell. In such a system the cell represents only about 20 percent of the cost, so its design and implementation need not await future developments in technology. However, the use of more efficient cells allows the system to capture and convert more of the sunlight. OTA suggests efficiencies of 15–30 percent, and the cost of electric energy produced this way would be $50–$120 per MMBtu per year. [35, 78]

A further variant is to use the photovoltaic system in a cogeneration mode, using water or air to draw off heat from the collector for space and water heating. Such a system allows recovery of four to five times as much heat energy as electricity. It is nearly as efficient at collecting heat as a flat-plate collector and can reduce by one-half the cost of solar electricity. [79]

Wind Power

The wind was used as a source of energy until driven out by (primarily) hydro-produced electricity. It is now making a comeback; individuals and groups are installing wind-powered electric generators on their homes and farms, and active R. & D. is underway on advanced windmill designs. As the costs of conventional electric sources climb, wind becomes more attractive as a fuel-free source of energy.

Windmills are becoming commercially available in the price range of 40–60 cents per peak watt and in power ratings from a few kilowatts to several megawatts. [49, 4] Placed at locations having average wind speeds of 14 miles per hour, wind generators will produce about 1,250 kilowatt-hours per year for each kilowatt of rated power. [71] Thus the price of this equipment is 30–50 cents per kilowatt-hour per year, or $100–$150 per MMBtu per year.

Heat Engines

Solar energy may be used to drive heat engines, just as the heat from burning coal or fissioning uranium drives steam-powered turbine-generators in central power stations. A number of efficient engines that can operate at temperatures which are accessible via solar collectors exist or are under development, in the price range $100–$400 per kilowatt. [35] Assuming efficiencies of 15 percent and operating load factors (reliabilities) of 80 percent, and coupling them to suitable collectors, we find system costs of $40–$140 per MMBtu per year. These systems are complex and will require more maintenance than the relatively simple photovoltaic or wind systems.

Projection

Let us set as a goal the furnishing of 25 percent of current electricity production, or 1.75 quads per year, through these solar-based sources by the year 2000. Let us also, equally arbitrarily, assume that each of the three sources gives one-third of this output. Then we find the following:

TABLE B-11

	Annual investment (billions)	Number of jobs (thousands)			Energy saved (quads per year)	
		Direct	Indirect	Total	1990	2000
Photovoltaics	$3.6	69	53	122	0.16	0.58
Wind	5.3	91	81	172	.16	.58
Heat engines	3.4	31	59	90	.16	.58
Total	12.3	191	193	384	.48	1.74

Here we have assumed these programs start in 1985, after a period of technological development, build up to 1990, and are at a constant level of investment thereafter. We have determined the employment impact using:

For photovoltaics, two-thirds of the employment arising from demand placed upon Electronic Components (BLS Sector 101), one-third upon New Residential Building Construction (BLS Sector 15).

For wind energy, Electrical Industrial Apparatus (BLS Sector 95).

For heat engines, Engines, Turbines and Generators (BLS Sector 83).

8. Nonrenewable Energy Sources

Introduction of the various measures suggested in the preceding sections of this Part would substantially curb the consumption of nonrenewable fuels. Conservation measures would reduce the overall need for energy, and renewable energy forms would begin to replace the fuels that predominate today.

If we bring together the savings achieved with each of the CARE measures, we can find the total savings in 1990. To allocate the savings among the various fuels, we assume that they take place in the same proportion as the usage projected by DRI for each sector. Only fuels directly consumed in each sector are included in the savings; fuels used by the electric utilities are treated separately as inputs into that energy-producing sector. We find the following consumption pattern, compared with the Data Resources projection for 1990:

TABLE B-12

	Savings (quads per year)	End-use consumption (quads per year)	
		DRI	CARE
Coal	1.6	6.2	4.6
Natural gas	5.9	17.4	11.5
Petroleum	7.5	41.1	33.6
Electricity	8.8	13.5	4.7
Total	23.8	78.2	54.4

To determine the impact of these savings upon employment in each of the fuel-producing industries, as well as in those industries that supply them with goods and services, we compare the savings with the total consumption of each fuel, including the primary fuels used by electric utilities. The reduction in electricity use leads to substantial savings in primary fuels, which must be apportioned among the sources of electrical energy—coal, natural gas, petroleum, nuclear, and hydropower. To do this we assume that (1) the use of natural gas and petroleum is reduced to negligible levels, in accord with the widely accepted desire to avoid using these rapidly depleting fuels in situations where other fuels can serve equally well; (2) the contribution of nuclear energy is not raised above its current level, to avoid the manifold problems posed by an increasing quantity of fissionable materials and waste products; and (3) the contribution of hydropower is not reduced at all. We then find the following reductions in consumption of primary fuels:

TABLE B-13

	Primary fuel savings (quads per year)	Primary fuel consumption (quads per year)	
		DRI	CARE
Coal	13.9	28.1	14.2
Natural gas	7.1	18.6	11.5
Petroleum	12.8	46.4	33.6
Nuclear	11.1	13.3	2.2
Hydropower		4.3	4.3
Total	44.9	110.7	65.8

The fractional savings in primary fuels and in electricity resulting from the introduction of conservation and solar energy in 1990, compared to the DRI projection for 1990 and the 1977 level of consumption, are as follows:

TABLE B-14

	CARE compared to (percent change)—	
	DRI 1990 projection	1977 consumption
Coal	−49	−4
Natural gas	−38	−35
Petroleum	−28	−11
Nuclear	−83	0
Hydropower	0	+40
Electricity	−65	−29

These projected reductions in the use of nonrenewable fuels would affect both spending on consumption of these energy forms during 1990 and investment that year for future production. We assume the following effects upon the corresponding industries:

Reductions in current spending on coal mining, petroleum production, refining, and distribution, natural gas production and distribution, and electricity production (including the primary fuels that feed it) proportionate to the reduction in end-use consumption (Table B–12).

No change in investment in petroleum and natural gas exploration. The continued demand for oil and gas, along with the increasing difficulty of finding new domestic sources of these fuels, will necessitate a continued high level of exploration.

No investment in new electric powerplants. The projected consumption of electricity is 29 percent less than the 6.7 quads consumed in 1977. Currently existing plants, plus those now under construction and due to be completed within the next decade, will provide an excess of capacity, in this projection, by 1990. They will have useful operating lives of at least 30 years and, by that time, can be replaced by the solar sources discussed in the preceding section. Since the 1960's, electric utility construction has composed about 43 percent of all public utility construction (which includes not only electricity production and distribution facilities but gas utilities, sewage treatment plants, water systems, and telephone and telegraph facilities). [80, 81] We assume that this proportion is maintained through 1990. (The BLS projections shows no unusual rise in spending on public utility construction, though some electric industry spokesmen have called for such an increase. [82] We also assume that 25 percent of electric utility construction is composed of transmission and distribution facilities whose construction continues, while plant construction costs must be supplemented by a 25 percent overhead for such utility expenses as land, insurance, and interest.

Using these assumptions, we find the following dollar savings:

TABLE B–15

	Reduction in annual expenditures (dollars in billions)
Current operations:	
Coal	[1] 2.4
Natural gas	[1] 7.9
Petroleum	[1] 21.5
Electricity	71.0
Investment: Electricity	16.0
Total	118.8

[1] These figures give the reduction in spending for end-use consumption only, not for electricity production, and are obtained from the ratio of the first column of Table B–12 to the second column of Table B–13 and the BLS projections of output in 1990. They include expenditures for transportation and wholesale and retail trade, as well as production.

To estimate the employment impact of these reductions in spending, we must examine each energy source in turn, since the proportionality assumption inherent in the use of the input-output method cannot be applied to much of the energy industry:

We expect employment in the coal industry to be approximately proportional to its output. With the reduction in consumption, fewer mines will have to be opened and fewer coal trains loaded, resulting in fewer work crews and less administrative overhead. As Table B–14 shows, there is an overall reduction of 49 percent from projected 1990 levels. Using the BLS projections for Coal Mining (BLS Sector 11) and the Rail Transportation Sector, we find a reduction of 263,000 direct jobs and 397,000 total jobs.

We expect little or no reduction in employment in the natural gas industry as a result of the projected 38 percent reduction in output. Employment depends on the scale of this industry, not its output. The distribution network and the number of customers to be served will not change very much, since some industrial heating, home cooking, etc., will still use natural gas, and there will still be a need for back-up to the renewable energy systems.

We expect a major share of the 28 percent reduction in petroleum use to be achieved through reductions in imports, which are projected by BLS to amount to 57 percent of petroleum consumption in 1990. Thus, domestic production will not decline as much as total consumption, and we expect no reduction in the number of petroleum refineries or other petroleum distribution facilities. As in the case of the gas industry, employment in these facilities depends more on their number than on their output, so we expect little or no change in employment. On the other hand, we expect some reduction in the number of persons engaged in selling petroleum (especially fuel oil) to residences and industries. Assuming a wholesale markup of 25 percent and using employment projections for Wholesale Trade (BLS Sector 129), we find a reduction of 103,000 direct jobs and 147,000 total jobs. [37]

Today about 22,000 workers are employed in uranium exploration, mining, refining, and enriching, and much of their output goes to military uses and research. [83] An expanded nuclear industry such as is envisioned in the DRI projections would rely to a great extent on imported and reprocessed uranium. Thus we expect little reduction in employment in this industry in our 1990 projections, and none compared to today.

As with the case of natural gas, employment in the electric utility industry depends more on the extent of the industry—the number of powerplants, the size of the distribution network, the number of customers served—than on its annual output. Only about 15 percent of those employed in the industry work in the powerplants; the rest maintain and repair the distribution system, provide customer services, and carry out various clerical and administrative tasks (e.g., billing, meter reading, etc.). [83] Most employees, in other words, are more part of the overhead than of output-related costs. Thus, BLS projects a 115 percent growth in output by 1990 but only a 19 percent increase in employment. If we assume that our projected 65 percent reduction in electricity consumption reflects a cut in the number of powerplants but not in the extent of the distribution system or the number of customers (who still need electricity for various operating needs and as backup for solar systems), we expect about a 10 percent reduction in employment, or a cut of 50,000 direct jobs and about 100,000 total jobs.

The elimination of electric utility construction reduces Public Utility Construction (BLS Sector 17) by 32 percent. Using the BLS projection, this leads to a reduction of 264,000 direct jobs and 493,000 total jobs in 1990.[4]

Putting these together, we have the following reductions in employment as a result of the reduced consumption of nonrenewable fuels and reduced investment in energy production facilities:

TABLE B-16

	Number of jobs (thousands)		
	Direct	Indirect	Total
Current operations	416	228	644
Investment	264	229	493
Total	680	457	1,137

9. The Disposition of Energy-Related Savings

The total CARE investment in 1990, and the cumulative investment through 1990, are:

[4] It may be noted that the direct jobs estimated here are consistent with the current employment of about 130,000 in electric powerplant construction and with the 6 percent per year growth in construction needed to achieve the DRI-projected electricity output in 1990. [84]

TABLE B-17

[In billions of dollars]

	Annual investment		Cumulative investment	
	Conservation	Solar	Conservation	Solar
Residential	7.8	14.8	67.1	127.3
Commercial	2.4	6.6	20.6	56.7
Industrial	5.3	6.6	45.6	104.0
Portable fuels		4.3		37.0
Electricity		12.3		45.2
Total	15.5	50.1	133.3	370.2
Combined total		65.6		503.5

The annual saving on nonrenewable fuels is $53.2 billion more than the annual CARE investment. If CARE investments are made out of current income, and if the suppliers of nonrenewable fuels and electricity do not raise their prices in response to the decline in sales (to maintain a target rate of return on their previous investment, service their debt, etc.), these savings are available to be spent on additional goods and services. If these purchases are made in the same proportion as other purchases in 1990 of consumption and investment goods, this will create 1,870,000 additional jobs. (This is obtained from the ratio of the total number of jobs in the BLS projection, 114.0 million, to the GNP produced by that level of employment, $3,241 billion, or 35,174 jobs per $1 billion of average demand.)

On the other hand, energy suppliers may raise their prices, or earlier CARE investments may have been financed by borrowing, and there may then be fewer such jobs created. Those who have borrowed funds will be using a portion of their current income to pay interest and principal on these loans. They will have less money available to purchase additional job-producing goods and services. If loan payments can be held down by providing long-term loans at low rates of interest for CARE investments, and if energy industry price increases are limited, there will be substantial numbers of jobs created in this way (as well as substantial amounts of goods and services available to consumers who could otherwise not afford them.) As long as the loan payments and price increases in 1990 amount to less than 20 percent of the cumulative CARE investment, there will be net savings available and additional jobs produced. Clearly, a wide variety of financing options exist that can make this possible.

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