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SUMMARY

As our energy needs increase and our energy resources dwindle and as we become more dependent on foreign sources, alternative energy sources must be sought out. Solar energy, being a non-depleting clean source of energy, is shown to be capable of providing energy in all the forms in which it is used today. It can be used to generate electricity, for heating and cooling buildings, and for producing clean renewable gaseous, liquid and solid fuel. There is little question of the technical feasibility for utilizing solar energy. The chief problem is rapidly providing innovative solutions that are economically competititive with other systems.

INTRODUCTION

President Nixon in his energy message of June 1971 pointed out the national need for clean energy. He asked that the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) assess the potential of solar energy for satisfying a significant portion of our nation's enormous and growing appetite for energy. Accordingly, the Solar Energy Panel was formed under the co-chairmanship of NSF and NASA. The panel was comprised of nearly 40 scientists and engineers and several economists, sociologists, and environmentalists. The results of their study are presented in reference 1. The panel recommended that the federal government take a lead role in developing solar energy research and development programs with three objectives: (1) economical systems for heating and cooling of buildings, (2) economical systems for producing and converting organic materials to liquid, solid, and gaseous fuels or to energy directly, (3) economical systems for generating electricity. They further recommended that the government fund a 15-year program that would total 3.5 billion dollars if all recommended approaches continued to show promise to final demonstration. Demonstration plants would be cost shared with industry.

NSF has been assigned the primary responsibility for conducting a national solar energy program. It is based on the findings and recommendations of the Solar Energy Panel. The funding level for the NSF solar energy program is expected to increase from about $4 million in FY'73 to $12 million in FY'74, while the NASA-supported program for FY'73 and FY'74 amounts to about $1 million.

IMPACTS OF THE NATIONAL NEED FOR ENERGY

The need for clean abundant supplies of energy and our difficulty in meeting the demand has resulted in the so-called "Energy Crisis." This energy crisis has both near-term and long-term aspects. The near-term problem results primarily from inadequate plant capacity to process and deliver petroleum and natural gas during a period of rapidly rising demand for these fuels. The environmental restrictions on discharge of sulfur oxides have shifted demand from high-sulfur coal to low-sulfur oil and natural gas. At the same time, the automotive public has purchased an increased number of large automobiles that consume large amounts of gasoline. During this period of rising demand, the petroleum suppliers expanded plant capacity too slowly to meet the demand.

For the long term, the more basic issue is the relation between the nation's demand for energy and the basic supply.

The United States demand for energy is illustrated by figure 1. By the year 2000 our need for energy is projected to triple (ref. 2). If we use energy at the rate projected, our energy reserves (relative to 1970) will decrease as shown in figure 2. The projections are based on estimated reserves forecast by the oil and gas industry. the United States Geologic Survey and the Atomic Energy Commission (ref. 2). Oil, gas, and uranium-235 (required for our conventional nuclear reactors) are expected to be exhausted shortly after 2000 A.D. unless consumption patterns are changed or new resources utilized. Natural uranium, which is mostly uranium-238 (used by the liquid metal fast breeder reactors), and coal are seen to last for several centuries because of relatively abundant supplies that exist in the United States.

With the increase in energy consumption comes an increase in pollutants. Figure 3 shows the relative annual production of pollutants relative to the year 1970 (ref. 2). Until 1980 a decrease in pollutants is projected. This is due to the nation meeting the anti-pollution standards that have been set. Beyond 1980, however, the large increase in energy demands once again increases pollutant production unless the pollution standards are further tightened. Not shown is the environmental impact of strip mining and the impact of the production of long-lived radioactive wastes from nuclear powerplants which must be stored for 1,000,000 years before they can be safely released to the environment.

Yet another problem brought on by the large consumption of energy is the reliance on foreign nations for our oil and gas supplies. The National Petroleum Council forecasts (see fig. 4) a net deficit in balance of payments in 1985 of at least 20 billion dollars. More than half of our oil will be imported by 1985. The effect on our economy is of great concern. Of greater concern is our major dependence on foreign sources of energy that is vital to our national security and well being. What will happen as other nations of the world who need energy for survival compete with us for the foreign sources is a matter for serious contemplation.

POTENTIAL SOLUTIONS

There are four major potential solutions to the shortage of oil and gas that can be considered seriously because they are technically feasibile, they could supply the large energy needs of the United States, and they are available domestically. These potential solutions are gasification and liquefaction of coal, nuclear energy to produce electricity, geothermal energy and solar energy.

The use of coal involves solution of the SO_2, NO_x, and particulate pollution problems and will require the reclamation of strip-mined land in most regions. These problems are not insurmountable, but will result in increased costs. If coal is to supply a larger portion of our energy needs, technology is needed for the large-scale, practical, economical and efficient conversion of coal to oil and to gas.

The use of nuclear energy to solve the energy problem introduces safety questions and management of the large amounts of radioactive waste products that are generated by the fission of uranium. The technology needed for practical utilization of nuclear energy requires the successfull development of an economical and safe breeder reactor. An accpetable and safe means for handling the vast amount of radioactive waste products that will be generated and that require storage or disposal with assurance of no release for 1,000,000 years could be the most difficult obstacle to overcome.

Geothermal energy is limited presently to those areas where steam is naturally available at the earth's surface, such as the geysers area north of San Francisco. Systems using hot water from drilled wells are under investigation, but the economic feasibility and the pollutant and environmental impacts have not been fully assessed.

There are no major environmental problems associated with the utilization of solar energy except for its possible impact in our land use. Solar energy is diffuse and will require large amounts of land for solar collector "farms" or for farms for growing crops or forest of trees for producing fuel. The impact of land usage can be minimized by utilizing land already used for other purposes, such as collectors on the roofs of buildings or over parking lots. The NO_x problem associated with the burning of present fuels will also be present if solar energy is converted to a solid, liquid or gaseous fuel. Also solid solar-derived fuels will have particulate problems similar to those associated with the burning of coal.

Thermal pollution caused by the combustion of fossil fuels and the fission of uranium are primarily a local problem today. The effects of this added thermal energy on the earth's thermal balance is not understood at this time. The utilization of solar energy collected on the earth will have a minimal effect on the earth's thermal balance, but will cause local changes as the energy is collected in one area and used in another. However, if solar energy is collected in and beamed to earth in the form of microwaves to be converted to electrical energy, the thermal balance will be disturbed in the same fashion as with fossil and nuclear power. Such a satellite system for converting solar energy to electrical energy has been proposed (ref. 3) and is discussed briefly later in this paper.

The solution to the technical and environmental problems associated with the use of coal and nuclear fuel is expected to substantially increase the cost of energy. Estimates are that energy costs may triple in the next ten years because of the dependence on foreign sources, the cost of replacing oil and gas sources with nuclear and coal, and the cost of eliminating pollution and environmental problems. As the costs of utilizing fossil and nuclear fuels increases, alternative sources such as solar can become economical if methods of utilization are researched and developed.

THE SOLAR ENERGY SOLUTION

It is imperative that new sources of clean energy be sought out. This paper considers the use of solar energy. The chief problem of using solar energy in the past has been achieving cost-competitive systems. There is no question that production of solar energy is technically possible. What is needed now is technology that will reduce the cost of solar energy systems and make them practical. Innovative approaches, simple efficient optimized designs that are the result of sound systems approaches and careful management of technology development programs are the necessary ingredients to demonstrate economical and practical solar energy solutions to the nation's energy-shortage problem.

Solar energy is a clean, non-depletable energy source that is available nearly everywhere and that is limited only by the available land area. Solar energy is diffuse and variable but abundant. See figure 5. In space at earth's distance from the sun the solar radiation available is 130 watts/ft^2. Considering the day-night cycle and the seasonal variation of solar flux, and the attenuation due to atmospheric conditions (clouds, dust, and smog), the average energy falling in the United States on a year-round basis is 17 watts per ft^2.

This is equivalent to 600 times the current total energy needs of the United States. At an average efficiency of conversion of 5 percent, it would take less than 4 percent of the United States land area to supply all our current energy needs.

In What Form is Solar Energy Needed?

The United States uses energy in different ways. The primary uses can be classified into (1) generating electricity, (2) heating and cooling buildings, and (3) providing fuel for transportation and industrial processes.

At the present time, approximately 22 percent of our total energy consumption is used for generating electricity, 25 percent for providing thermal energy for buildings, 23 percent for transportation and 30 percent for industrial processes (ref. 2). An important point to note is that the direct use of fuel (especially oil and gas) for transportation, heating, and industrial uses accounts for more than 75 percent of our energy use. What we need more than any other source of energy is a source of liquid and gaseous fuel.

Solar energy can be utilized to provide all of our various energy needs. It can produce electrical energy, provide energy for the heating and cooling of buildings and it can be used to produce clean renewable supplies of liquid, gaseous, and solid fuels. See figure 6.

Electricity from the Sun

Several methods of generating electricity from solar energy are presented in figure 7. They are:

1. Direct conversion of solar energy to electricity using solar (photovoltaic) cells.

2. Collecting of solar energy as heat to heat fluids that can be used to operate heat engines. These engines are used to drive electric generators.

3. Using solar energy to grow biological material that can be converted to fuel. The fuel is then used to operate heat engines that are used to generate electricity. (This is discussed in a later section.)

4. Using the solar-heated upper layers of the ocean water in conjunction with the cold lower depth of the ocean to operate a low temperature difference heat engine. The engine is used to drive an electric generator.

5. Using the wind (which is generated by the sun) to operate a wind generator to produce electricity.

Solar cells in space. - Many of our space vehicles and experiments obtain their energy needs by the use of solar cells which directly convert the sun's energy to electricity. Figure 8 illustrates a large solar photovoltaic array that is designed for use by a manned space station. This is one-fourth of an array that produces a total of 100 kilowatts of electrical energy. The 25 kilowatt segment shown here is 20 feet wide and 80 feet high.

Figure 9 shows a proposed concept for using solar cells in synchronous orbit to make power for use on the ground. This is the Satellite Solar Power System (SSPS) concept. See reference 3. The electricity that is generated by the solar cells is converted to microwaves and beamed to the earth. On the earth, a receiving station converts the microwaves back to electrical power through a device called a rectenna. The concept shown generates 5000 megawatts on the ground. The solar array panels shown are about 7 miles by 3 miles in length and breath. The total system weight in orbit is about 25 million pounds. It would take 80 SSPSs of this size to supply all our projected 1985 electrical needs.

At the present time the cost of a SSPS system would be prohibitive. Solar cells alone would cost $125,000/kw or more (ref. 4). Neglecting the cost of placing the array in synchronous orbit and assembling the system would result in a power cost of 4800 mills/kw-hr for electricity compared to conventional electricity costs of about 7 mills/kw-hr. The projected goal for the SSPS concept is to reduce the costs to $500/kw with an electricity cost of 12 mills/kw-hr. To achieve this goal, a factor of about 1000 reduction is required in solar array cost; a factor of 100 reduction in cost of placing the station in synchronous orbit; and a factor of 10 reduction in the weight per kilowatt. The primary emphasis on technology will be directed toward reducing the cost of solar cells.

Solar thermal systems. - The heat that is generated by absorbing the sun's radiation can be used to heat a fluid such as water. The stream that would be generated could be used to operate a steam engine. An early solar energy powerplant shown in figure 10 was demonstrated in the Paris Exposition of 1878. A parabolic reflector concentrated the sun's radiation to produce steam that powered a steam-engine-operated printing press. Figure 11 shows a powerplant utilizing cylindrical solar collectors to concentrate the sun's energy on pipes that produced steam to operate a 50 horsepower water pump for irrigation. This was built in Egypt in 1913 and operated during the First World War. A 1000 kilowatt high temperature furnace completed in France in 1971 is shown in figure 12. It concentrates solar radiation from a large array of mirrors on a nearby mountain side onto a one square foot area. It is capable of heating a ton of metal to temperatures of several thousand degrees Fahrenheit. A solar powerplant for generating electricity of the type proposed by the Meinels (ref. 5) is shown in figure 13. Several square miles of desert would be covered by a large number of cylindrical parabolic reflectors that produce steam. The steam that would be collected from the solar collector "farm" would be used to produce electricity in a more or less conventional steam turbine central station. Another technique shown in figure 14 eliminates the need for the miles of piping that is needed to collect the steam generated by the large collector farm (ref. 6). The sun's rays are concentrated onto a single central boiler located on a tower. The mirrors are movable so that sun's rays are always focused onto the boiler.

Various estimates have been made of the cost of producing electrical energy by means such as these. They range from $300 to over $3000 per kilowatt for the capital cost. The cost of the electricity produced would vary from 7 to 70 mills per kilowatt-hour. If all the electric energy to meet our nation's total electrical power needs were produced in our southwestern desert regions, it would take an area of about 2000 square miles of solar collectors for an overall system efficiency of 20 percent. Of course all the power needs would not be generated in one location. The degree of dispersion is a matter that is receiving attention in current systems studies. In fact, one advantage of solar produced electricity might be that powerplants could be much smaller and widely dispersed, minimizing the need and cost for transmission lines.

A major problem with producing electricity from heat generated by the sun is the energy storage that would be required for night-time and inclement-weather operation. The cost of systems for energy storage is a large contributor to the high cost that is currently projected for these systems. The largest cost factor, however, is the cost of the sun-tracking concentrating solar collectors. Low cost designs that can withstand the environmental conditions such as wind, weather and dust require innovative approaches with demonstration of long, reliable and satisfactory performance under all conditions.

Electric power from ocean temperature difference. - The ocean temperature difference (ΔT) system that utilizes the temperature difference between warm surface waters and cold, deep, ocean waters to operate a heat engine is a system for generating electricity that has been demonstrated in the past. See figure 15. It is proposed that such systems be anchored in the Gulf Stream off the southern cost of Florida. Here the upper ocean layers are warmed to about 80° F by the sun. The warm water is used to vaporize a fluid that drives a turbine. The turbine turns a generator for making electricity. The fluid after it has passed through the turbine is condensed by a cold water supply with a temperature of 40° F. It is piped up from depths of about 2000 feet.

Systems using the ocean ΔT have been demonstrated by Claude who built a 22 kilowatt system in Cuba in 1929 (see ref. 7) and the French who built two 3500 kilowatt systems in the 1950's. The major advantages of such a system are that no collectors or storage are required. The ocean both collects and stores the solar energy for day/night cycles and inclement weather. See reference 8 for further discussion.

The ocean ΔT system has the potential to make a major contribution to our energy needs. For example, it has been estimated that less than a 0.3° F drop in Gulf Stream would supply all our 1985 electrical needs.

The ocean ΔT does have some key technology needs that must be solved before this system can become practical. The first is concerned with the cold-water duct that is about 30 feet in diameter and 2000 feet in length. A major problem is how to support and anchor such a duct with the lateral forces exerted on it by the varying ocean currents flowing in opposite directions at different depths and by storms and wave action. Second, because of the low ΔT, large heat exchanger surfaces are required to extract large amounts of power. Methods for fabricating low cost, large, low-leakage heat exchangers must be demonstrated. Third, the ocean ΔT system must be compatible with the ocean. It must withstand corrosion, hurricanes and the possibility of debris, fish, etc. from clogging heat exchanger passages. In addition practical and economical methods for operating and maintaining a large plant at sea that delivers its energy to shore must be demonstrated.

Preliminary cost estimates by advocates of the ocean ΔT system range from \$300 to \$500/kilowatt which indicate that the ocean ΔT system could provide competitively priced electricity. However, these estimates must be verified by demonstration systems.

Electric power from wind. - Wind power can and has been used to generate electricity (which, of course, is derived from solar heating of the atmosphere). A large 1250 kilowatt wind generator (fig. 16) was built in Vermont in the early 1940's and delivered electricity directly into the local power grid (ref. 9). Wind generators are currently being used to generate small amounts of power around the world. Figure 17 shows a modern German design that produces 10 kilowatts. A Danish wind generator is shown in figure 18 that generated 200 kilowatts of electricity. Figure 19 shows an artist's conceptual design for a streamlined wind generator for off-shore power generation (figures supplied by Grumman Aerospace Corporation). The figure illustrates that if attention is paid to esthetics, designs could be made attractive.

There is no question about the technical feasibility of generating electricity from wind generators as evidenced by the many demonstrations. The only question is whether electricity can be generated reliably and competitively by wind power and is there enough wind power available to make a signficant impact on our energy needs?

Estimates by advocates of wind power in this country claim there is enough wind power to supply all our current electrical needs and that winds in the Great Plains alone could supply half (200,000 megawatts) of our 1985 electrical needs (ref. 10).

The question that comes up most often when discussing wind power is that of energy storage. What happens when the wind stops? Energy storage is necessary to make it possible to use individual wind generators for small-scale applications such as homes or small communities. However, for large applications wind generators could be added to systems that have storage such as networks with pumped water storage. Or wind generators could be added to produce power for the grids of conventional hydroelectric plants. In addition, wind-generators could be added to any grid to feed power whenever the wind blows. The fuel consumption of the conventional powerplants would thus be reduced in direct proportion to the energy supplied by the wind. The fuel in this case could be considered to be equivalent to an energy storage system.

Areas of the United States where practical application of large-scale wind-generators may be possible need to be determined. Storage systems could be desirable but they are not essential for all applications. Analysis of wind data is needed to determine whether the networking of large numbers of generators without storage would be practical considering the possibility that it is not likely that the wind would stop over a very large network at the same time.

Costs of previous demonstrations and estimates by present-day advocates range from $200/kilowatt to $650/kilowatt with a cost of electricity from 7-15 mills/kilowatt-hour. Electricity from wind appears to be an attractive alternative that deserves serious evaluation.

Solar Energy for Heating and Cooling Buildings

Approximately 25 percent of our present energy consumption is used for heating and cooling buildings. This energy demand is met chiefly by the use of gas and oil. Supplying this thermal energy for buildings by solar energy would save major quantities of our dwindling supplies of gas and oil for other uses.

Solar energy can be utilized for heating and cooling of buildings by utilizing flat-plate collectors (see fig. 20). These collectors consist of a surface that is used to absorb the sunlight. This surface is covered with one or several panes of glass which reduce re-radiation and convective heat losses. The collector is insulated on the sides and back to minimize conduction and convection losses.

Water, air or some other fluid is passed through the collector and can reach temperatures from 140° F to greater than 200° F. The thermal energy from the fluid is stored in a heat storage tank to provide energy for night time and inclement weather. The thermal storage can be in the form of sensible heat of water or rocks, or in the latent heat-of-fusion of special materials.

Coupled to the heat storage system is a heating loop and a cooling loop. The heating loop transfers heat from the thermal storage system to heat the building in cold weather. The cooling loop transfers heat from the thermal storage to operate an absorption or mechanical air conditioning system for warm weather. Also connected to the heat storage loop is an auxiliary heater. The purpose of this heater (which uses conventional fuel) is to supply thermal energy to either the heating or cooling system during periods of inclement weather when the stored energy is inadequate.

More than 20 buildings have been or are presently heated with solar energy in the United States. Figure 21 shows an office building in Albuquerque, New Mexico. Solar energy has provided 75 percent of the heating load for this building. Other buildings that have been successfully heated with solar energy are shown in figures 22, 23, and 24. See reference 11.

None of the solar-heated homes have solar-supplied air conditioning. The addition of air conditioning would make the solar energy systems for buildings more competitive. Systems could then be utilized nearly 12 months of the year. Solar supplied air conditioning will also help reduce summer peak-load requirements of our electric power utilities.

The NSF/NASA Solar Energy Panel report estimates that by 2020 35 percent of the thermal energy for buildings in the United States could be supplied by solar energy. In areas and buildings where solar energy is used, it is estimated that solar energy will supply an average of 75 percent of the buildings' thermal energy needs.

Technology improvements are needed in the flat plate collectors and the air conditioning systems. For the solar heating and cooling systems to be economically competitive, collectors of 50 percent efficiency must be developed at a manufacturing cost of about $\$2/ft^2$. Present lower temperature collectors for heating hot water are available at about $\$4/ft^2$. Commercially available absorption air conditioners can operate at temperatures of 220° F, but their coefficient-of-performance (C.O.P.) is low. Higher collector temperatures would increase the C.O.P. of absorption systems and may also make dynamic mechanical systems attractive for solar heating/cooling applications.

Economic studies have indicated that solar heating is less expensive then heating by electricity anywhere in the United States. However solar energy is not competitive with gas or oil heating in most places (ref. 11). If solar air conditioning systems can be developed, however, the picture would change because the collector cost would be shared by the cooling system as well. For example, it is estimated that it costs about $300/yr for fuel to heat and cool the average house. These fuel costs could pay for a $3000 solar heating/cooling system mortgaged over 15 years. With the increase in fuel costs and reduction in solar system costs, solar systems will pay for themselves in shorter periods of time.

Clean Renewable Fuel Sources from Solar Energy

At the present time the direct use of gas and oil supplies nearly 75 percent of all the nation's energy needs. The United States is rapidly running out of domestic supplies of gas and oil. Several processes for producing fuel from solar energy are shown in figure 25. Hydrogen can be produced by electrolysis using electric power from solar-generated electricity. Land and water plants can be grown, processed and dried to provide clean solid fuel for use in present powerplants in place of coal, oil or gas.

Land- or water-grown organics can be converted to gas or oil. The techniques used include pyrolysis, chemical processing, and biochemical reactions.

Pyrolysis is a destructive distillation process that heats organics in the absence of air. A present demonstration plant (ref. 12) produces two barrels of oil (12,000 Btu/lb) from each ton of dried organics at a breakeven cost of about 75 cents/10^6 Btu.

In the chemical process organics are heated under pressure in a cover gas of CO. A small pilot plant demonstration (ref. 13) of this system indicates that two barrels of oil per ton of dried organics can be produced (15,000 Btu/lb) at a breakeven cost of about 87 cents/10^6 Btu.

Several biochemical or fermentation processes have been in use in the United States over the past 20 years as sanitary plants. These systems produce methane which is used as a source of heat to power pumps in sewage plants. These plants have not been optimized to produce a maximum amount of fuel. In an optimized system grown organics and wastes may be used to produce fuel economically.

A process currently in the laboratory research stage is the photolysis of water (ref. 14). This is a proposed method for separating hydrogen from water by the use of sunlight, blue-green algae and microorganisms. This process is thermodynamically sound but must be developed and demonstrated as a practical system.

As shown in figure 26, approximately 15 percent or 470,000 Mi^2 of United States land is presently used to produce food, and another 3 percent or 94,000 Mi^2 is kept in reserve as surplus land. We paid farmers nearly \$2.6 billion in 1971 not to grow crops on this surplus land. If this surplus land were used to grow crops for fuel production at present efficiencies of one percent, enough fuel could be produced to meet 20 percent of our current total energy needs. If this efficiency could be increased to 5 percent, then this land area could supply all our current energy needs.

To make fuel from crops economically feasible, crops with the highest Btu's per acre per year must be identified and developed. Also, low cost processing methods including harvesting, preparation, and transporation must be evolved. And, finally, low cost conversion systems for converting crops to gas and/or oil must be brought into operation on a very large scale basis.

Several preliminary cost estimates for producing fuel from organics indicate that such processes are close to being econimically competitive today (ref. 1). These costs are in the same range for natural gas and oil from \$0.50/10^6 Btu to \$1.20/10^6 Btu.

POTENTIAL IMPACT OF SOLAR ENERGY

Prediction of the impact of solar energy depends on (1) how much effort the nation is willing to expend on its development, (2) the success of the development of other energy sources, (3) the cost competitiveness of solar energy systems, and (4) on the judgement of the predictions. The NSF/NASA Solar Energy Panel concludes that "if solar development programs are successful, building heating could reach public use within five years, building cooling in six to ten years, synthetic fuels from organic materials in five to eight years, and generation of electricity in 10 to 15 years." And further, "solar energy could economically provide (by the year 2020) up to (1) 35 percent of the total building heating and cooling load, (2) 30 percent of the nation's gaseous fuel, (3) 10 percent of the liquid fuel, and (4) 20 percent of the electric energy requirements."

CONCLUDING REMARKS

Whether solar energy will make a smaller or larger impact than predicted will depend on (1) how scarce fuel becomes, (2) how practical and environmentally acceptable new sources are, (3) how seriously we view our dependence on foreign sources, and (4) what the alternatives are. With only a small fraction of the nation's expenditure for energy, our country has the ability to vigorously pursue the development of alternate energy sources (such as solar energy) that could have a major impact and that do not use our depletable resources. Alternatives should be made available as quickly as possible to reduce the drain of our gas and oil reserves. The cost for doing this compared to our annual expenditure on energy could very well be a small price for the potential benefit to be obtained. By developing and operating these systems for selected areas of the United States before the need becomes a crisis, it would be possible to implement practical proven systems in the most rapid and efficient manner possible.

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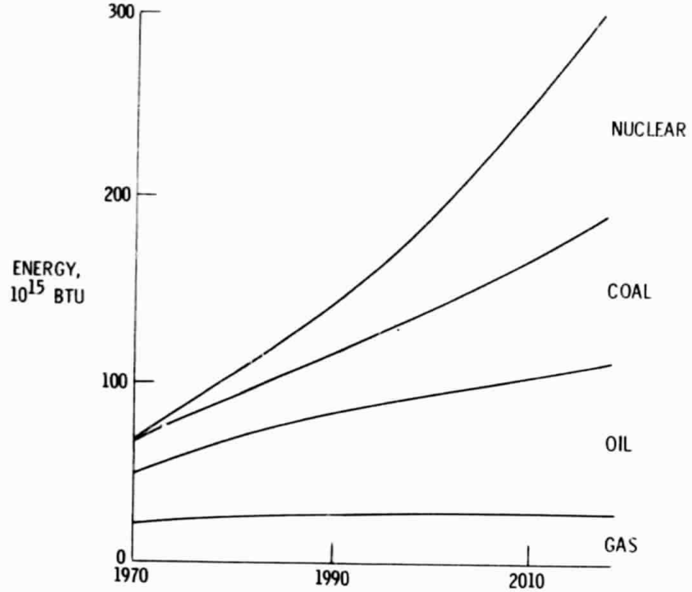

Figure 1

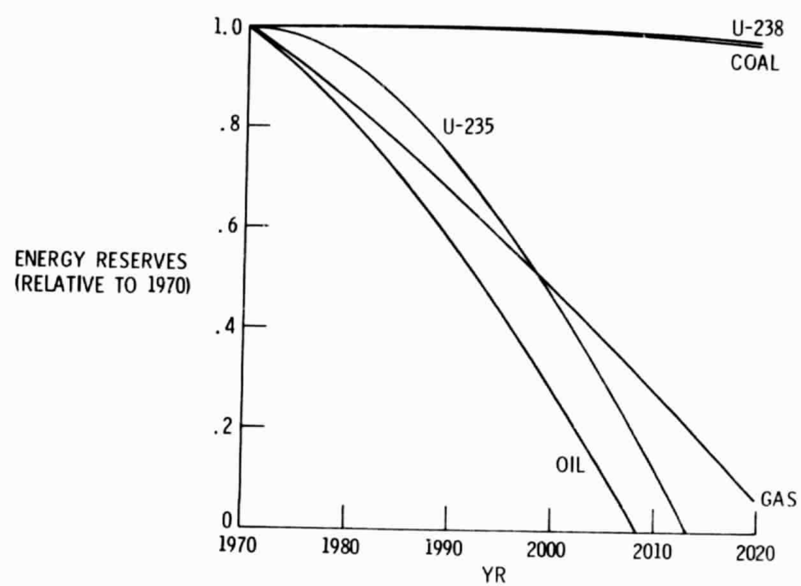

Figure 2

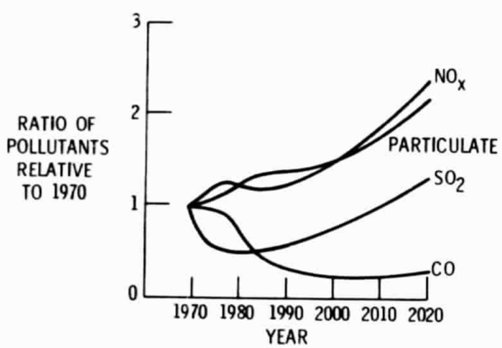

Figure 3

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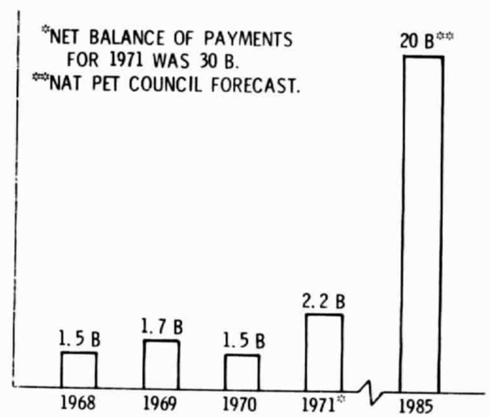

Figure 4

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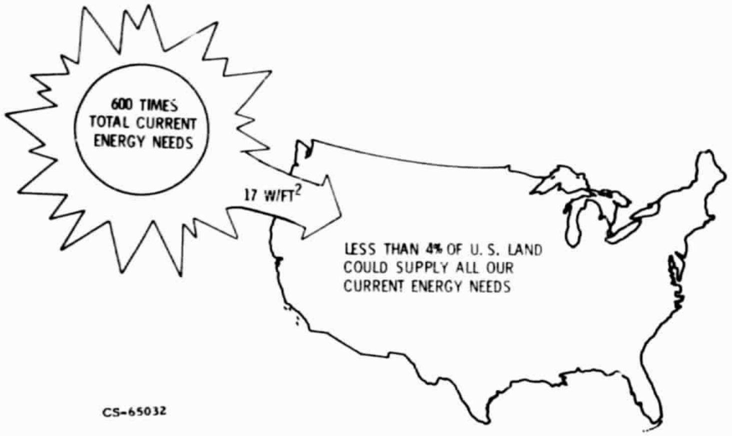

Figure 5

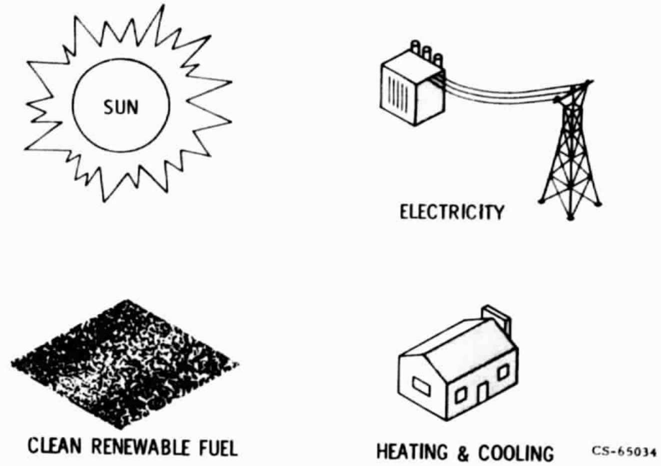

Figure 6

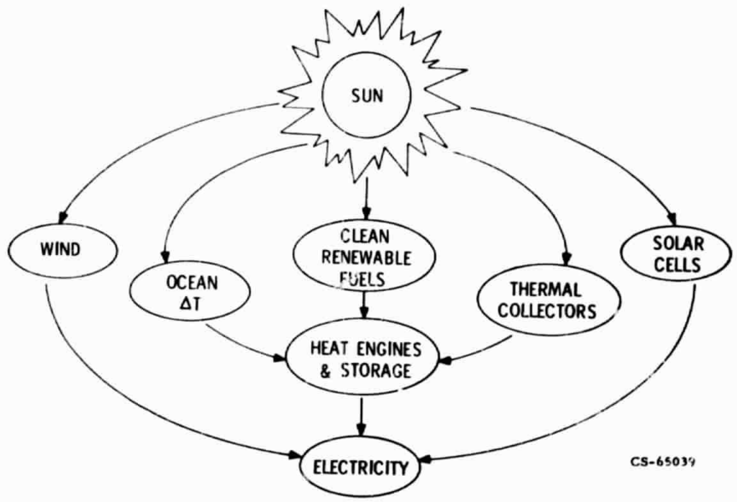

Figure 7

Figure 8. - 25 kW solar cell array built for manned space stations.

Figure 9. - Satellite solar power system.

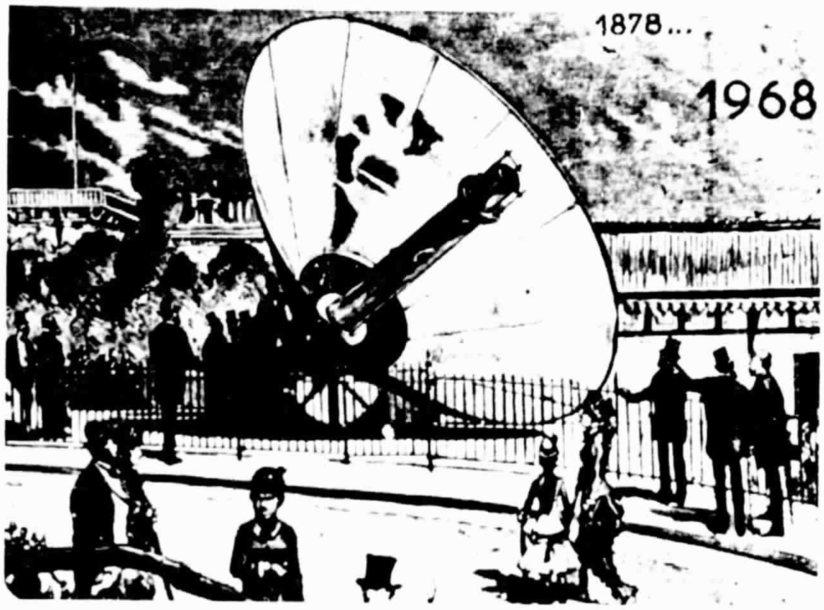

Figure 10. - Solar energy operated printing press, Paris Exposition, 1878.

Figure 11. - Focusing solar collector system used to operate 100 hp steam powered irrigation pump, Egypt, 1913.

Figure 12. - High temperature 1000 kW solar furnace, France, 1971.

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Figure 13. - Proposed focusing solar collector "farm" for producing steam for electric power production.

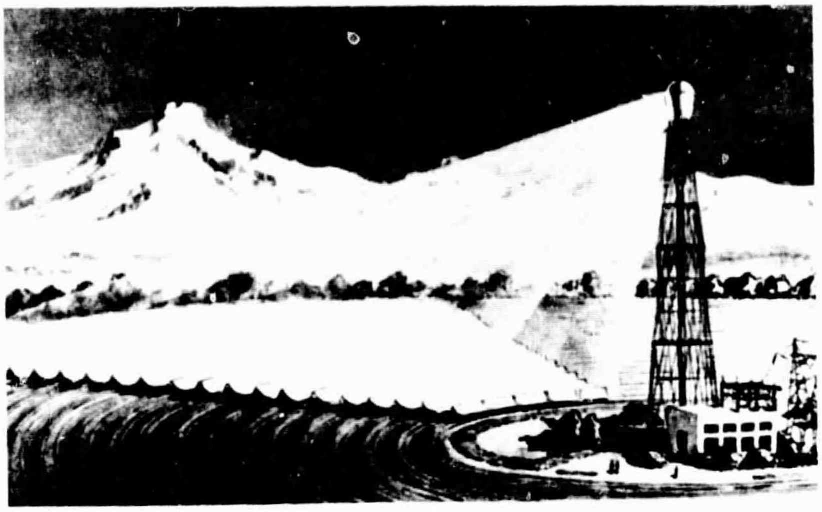

Figure 14. - Tower mounted steam boiler for producing electricity from solar energy.

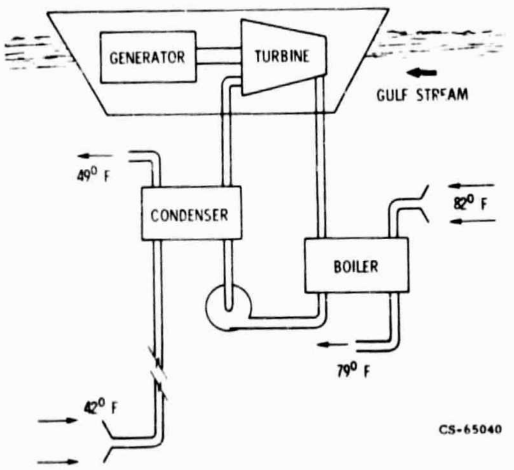

Figure 15

Figure 16. - 1250 kW wind electric generator, Vermont, 1941.

Figure 17. - Modern 10 kW wind generator, Germany.

Figure 18. - 200 kW wind generator, Denmark.

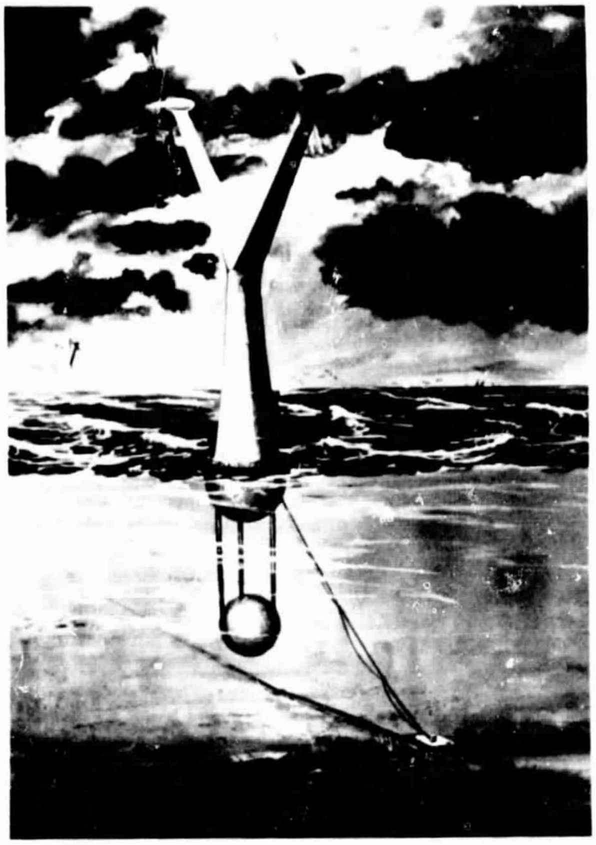

Figure 19. - Proposed multi-megawatt wind generator, U. S.

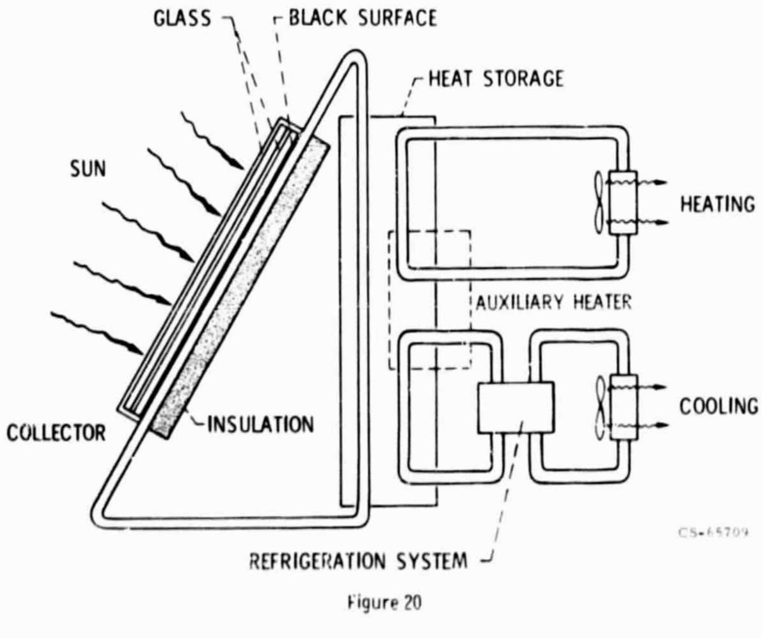

Figure 20

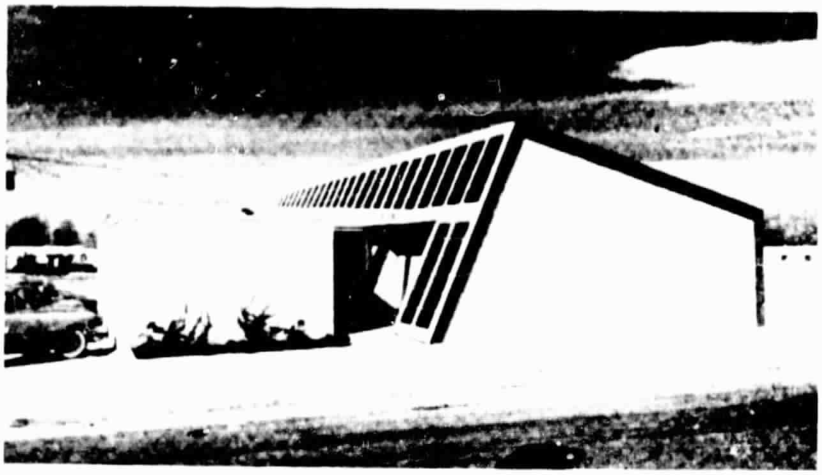

Figure 21. - Solar-heated office building, Albuquerque, N.M.

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Figure 22. - Thomasson solar heated home, Washington, D.C. area.

Figure 23. - Solar-heated house, Denver, Colorado.

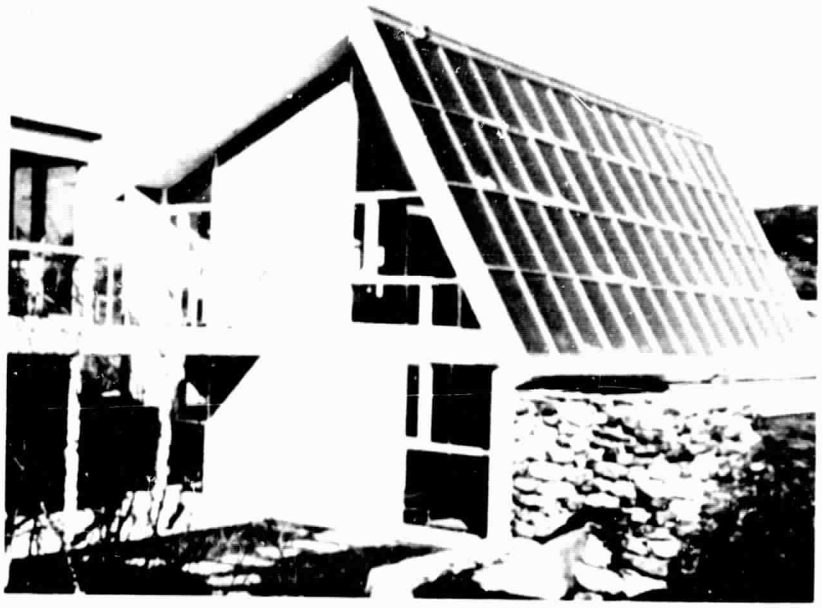

Figure 24. - Solar heated house, Massachusetts.

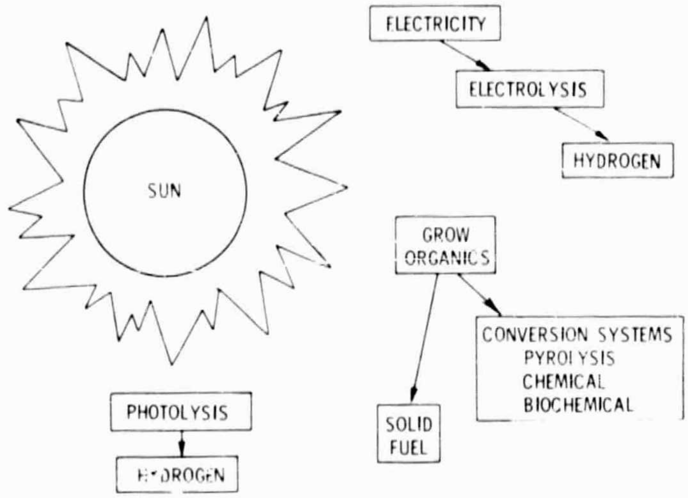

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Figure 25

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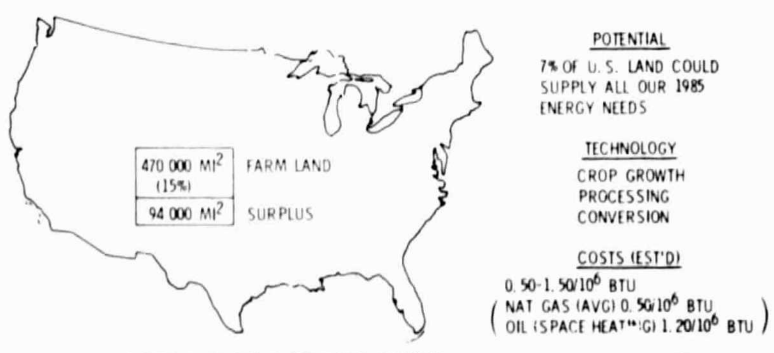
CLEAN RENEWABLE FUEL FROM SOLAR ENERGY



SURPLUS FARM LAND CAN SUPPLY FUEL TO MEET 10% OF OUR 1985 ENERGY NEEDS

CS-65030

Figure 26

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