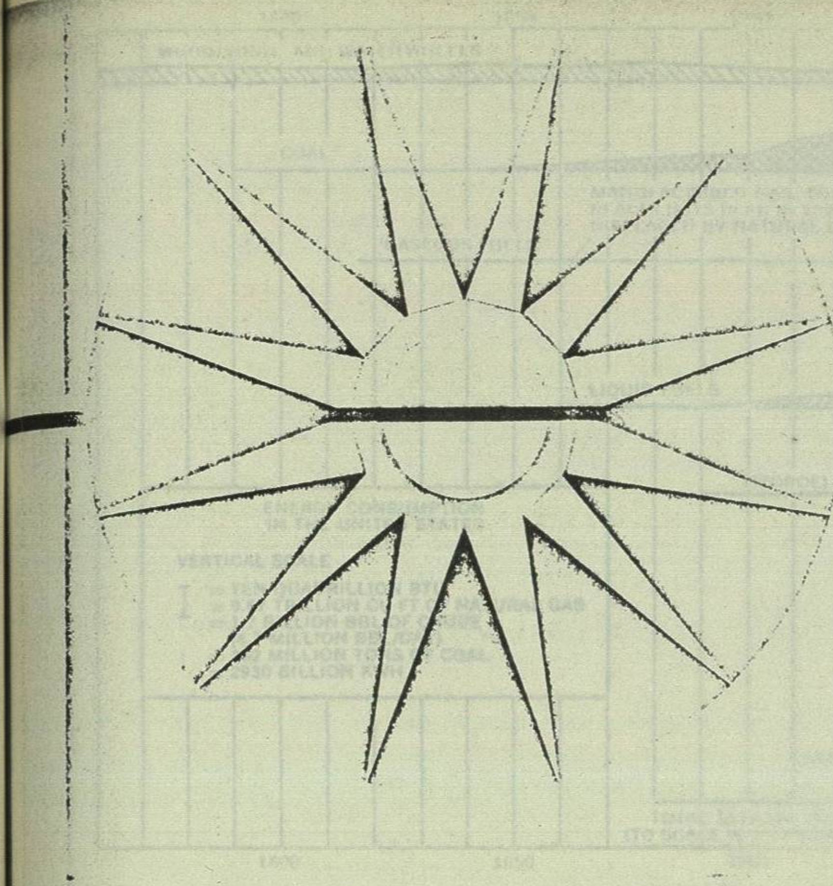

THE SOLAR ERA

Part 1—The Practical Promise

There has been a new source of energy every 30 to 40 years. The most recent is nuclear. By the century's end it could be solar energy to supplement both nuclear energy and the dwindling supplies of natural gas, oil, and coal. In addition to power and heat, this primal energy source—aided by chemistry and other resources—could produce fuels and lubricants for mobile equipment, rubber, plastics, and other petrochemicals.

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Had it not been for an abundance of fossil fuels—coal, oil, and natural gas—we might today have a solar-energy economy just as effective and efficient as our fossil-fuel economy. If need had forced man to devote the phenomenal ingenuity and inventiveness which he has displayed in the past 150 years to the development of devices for the utilization of solar energy instead of fossil fuels, we might, today, have huge solar-energy plants and complexes, similar to our oil-refinery and chemical complexes, where the sun's energy would be collected, concentrated, and stored to produce not only electric power, but a whole host of other things.

As it is, however, solar energy is so diffuse and intermittent when it reaches the earth that it is unlikely to be used extensively as long as fossil fuels remain abundant and readily accessible worldwide.

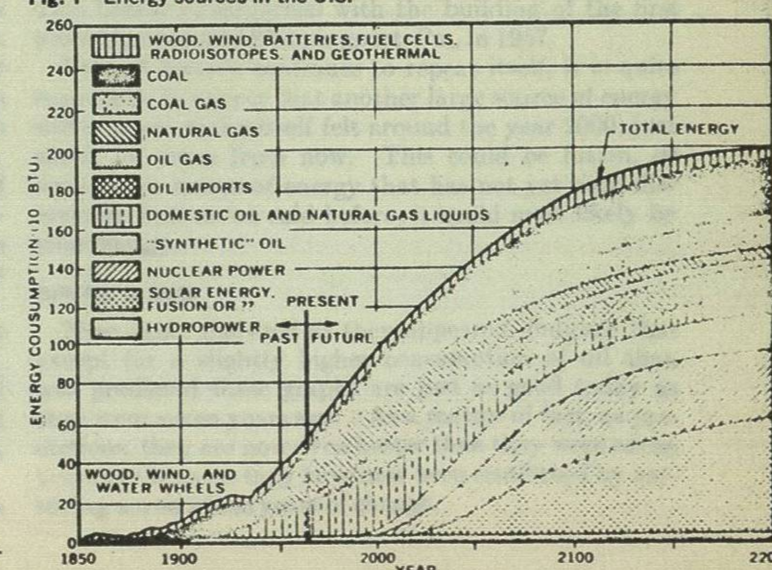
The large amount of area required to collect solar energy and the cost of the collection, storage, and conversion equipment involved prevent the *widespread* use of solar heaters, solar houses, solar cookers, solar evaporators and desalinators, solar power generators, etc., as long as fossil fuels are available to do the same job automatically, night and day, without cloud interference.

Now, though, we are beginning to become more and more aware of the fact that this bounty of fossil fuels cannot last.

Need for Solar Energy

In 1965, seven years ago, at the Solar Energy Society meeting in Phoenix, Ariz., the author presented the graph [1][1] which is shown in Fig. 1.

Fig. 1 Energy sources in the U.S.



[1] Numbers in brackets designate References at end of article.

Based on a paper contributed by the ASME Solar Energy Applications Group.

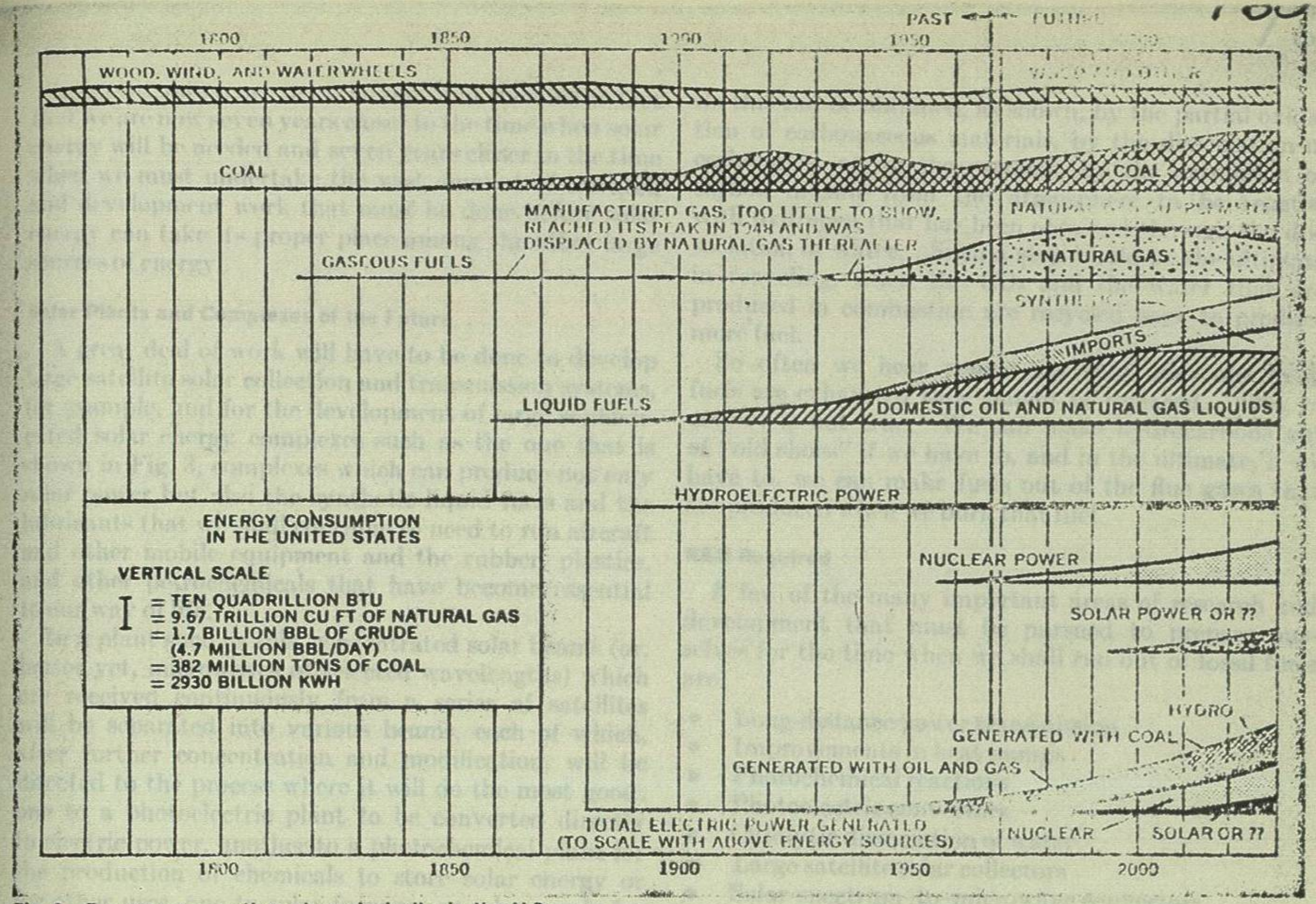


Fig. 2 Energy consumption, chronologically, in the U.S.

This graph showed that 30 to 50 years from now a new large source of energy will be needed to supplement nuclear energy and the world's dwindling supply of fossil fuels. It was suggested then that this new large source of energy might very well be solar energy.

It was also suggested then that this large amount of energy might "be collected and concentrated with satellites and then transmitted to the earth in concentrated beams of selected wavelengths to minimize diffusion and masking by the atmosphere."

It was pointed out that all the energy that was being consumed in the U. S. at the time could be collected from the sun with a single satellite only 21.5 mi in diameter.

Chronological Development

This graph has also been used in lecture tours made by the author for various institutions. For convenience, a modification of this same graph was used—one where the various segments are replotted, still to scale and in proportion with each other, but in a horizontal position as shown in Fig. 2 [2].

In Fig. 2, the various sources of energy are arranged in the order in which they were developed chronologically, and this graph shows very clearly that this country has developed a new source of energy every 30 or 40 years.

First, after wood, wind, and water wheels, it was coal. Although coal started being used in 1780 or so, it was not until 1870, after the development of several of the more modern energy-consuming machines such as steam engines, locomotives, cotton gins, lathes, etc., that coal became important.

Gas came next, in 1816, but this too did not become important until many years later when in 1930 natural gas began being piped long distances to market.

Oil was discovered in 1859, but it did not become an important item of commerce until 1919 when the self-starter was invented and the mass production of internal-combustion engines began.

The next new source of energy was hydroelectric power in 1890. This had to await the invention and development of electric power generators which became commercial with the building of the first steam-electric power plant in New York City in 1883. The bottom segment in Fig. 2 shows how the total electric power generation has grown since then.

Following the development of hydroelectric power generation, over half a century elapsed before another new source of energy was discovered—nuclear fission. This became commercial with the building of the first prototype plant in Shippingport, Pa., in 1957.

Now, if history continues to repeat itself, it is quite reasonable to expect that another large source of energy will begin to make itself felt around the year 2000, just about 30 years from now. This could be fusion, or some other source of energy that has not yet been discovered, but, as we said before, it could most likely be solar energy.

Still Up to Date

New data, analyzed as they appeared, indicate that except for a slightly higher consumption of oil than was predicted these graphs are just as good today as they were seven years ago. As a matter of fact, as predictions, they are now even better than they were seven years ago because they have now been reinforced by surviving seven whole years of change.

The only difference between now and then is the fact that we are now seven years closer to the time when solar energy will be needed and seven years closer to the time when we must undertake the vast amount of research and development work that must be done before solar energy can take its proper place among the other large sources of energy.

Solar Plants and Complexes of the Future

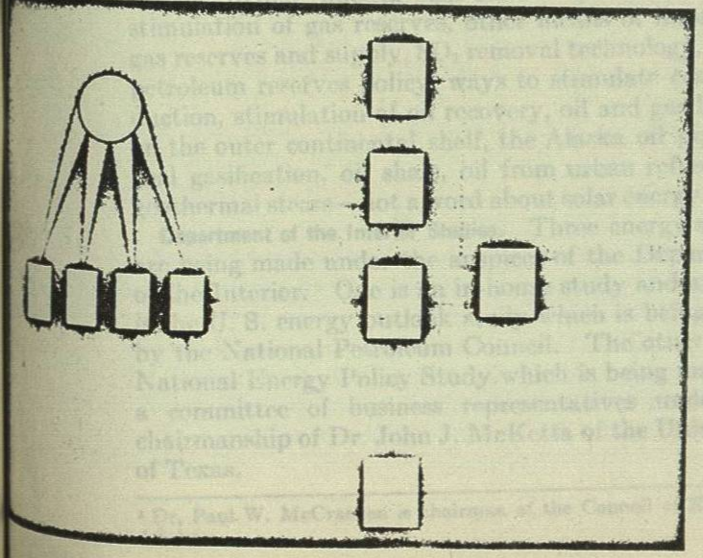
A great deal of work will have to be done to develop large satellite solar collection and transmission systems, for example, and for the development of large sophisticated solar energy complexes such as the one that is shown in Fig. 3, complexes which can produce not only solar power but also the synthetic liquid fuels and the lubricants that we shall continue to need to run aircraft and other mobile equipment and the rubber, plastics, and other petrochemicals that have become essential to our way of life.

In a plant such as this, concentrated solar beams (or, better yet, microwaves of selected wavelengths) which are received continuously from a series of satellites will be separated into various beams, each of which, after further concentration and modification, will be directed to the process where it will do the most good: one to a photoelectric plant to be converted directly to electric power, another to a photochemical plant for the production of chemicals to store solar energy or for other uses, one to solar furnaces or solar ponds for the production of heat for processing purposes, and others for more specific purposes such as the dissociation of water (with the aid of a catalyst not yet discovered) to produce hydrogen and oxygen which can be used as fuel for fuel cells in homes or as raw materials for the manufacture of fertilizers, synthetic hydrocarbons, and chemicals such as rubber, plastics, fibers, solvents, etc., as shown in Fig. 3.

Hydrogenation of Carbon Monoxide

In a complex such as this, the hydrogenation of carbon monoxide—a process that is already well known—can be used to produce hydrocarbons and chemicals similar to those that we use today. The hydrogen and carbon monoxide that are required to do this can be obtained, as shown, by the partial oxidation of carbonaceous materials, by the dissociation of carbonates, or, in the extreme, by the extraction of carbon dioxide from the atmosphere to be reacted with hydrogen that has been obtained through the dissociation of water. Such a step would be the ultimate in recycling, when the CO_2 and the water that are produced in combustion are recycled back to produce more fuel.

Fig. 3 Solar energy complex.



So often we hear people say that once our fossil fuels are exhausted they cannot be replaced. This, of course, is not true. We can make hydrocarbons out of "old shoes" if we have to, and in the ultimate, if we have to, we can make fuels out of the flue gases that are produced when we burn that fuel.

R&D Required

A few of the many important areas of research and development that must be pursued to prepare ourselves for the time when we shall run out of fossil fuels are:

- Long-distance power transmission
- Improvements in heat pumps
- Photochemical reactions
- Photoelectric convertors
- Catalytic dissociation of water
- Large satellite solar collectors
- Solar-spectrum-to-microwave convertors.

Because solar complexes such as that shown in Fig. 3 will have to be located in large uninhabited areas of the world, deserts and the like, we must learn how to transmit electrical energy over long distances more effectively, perhaps without wires.

We should also effect improvements in heat pumps so that these can be used to supplement the sun for the heating and air conditioning of homes and other buildings. Also, we most assuredly must do a lot more work on the study of photochemical reactions in which may lie the solution to the problem of storing solar energy.

We should, of course, continue the improvement of solar cells and of thermoelectric and thermionic devices for the direct conversion of solar energy to electricity. Also, we must improve the methods and the cost of producing, storing, and transporting hydrogen and oxygen so that these can be used in fuel cells in homes and also in the manufacture of chemicals and synthetic liquid fuels as we described before.

In addition, a great deal of work needs to be done on the development of large satellite solar collection and transmission systems. This idea was first suggested by the author in 1965 [1], and it has since been expanded upon and shown to be feasible, even with present technology, by Glaser [3-7]. The satellite solar collectors may be composed of solar cells which can be coupled directly to d-c-to-microwave convertors, as Glaser has suggested, or the collectors may be simple mirror-like parabaloid devices focused on laser-like convertors or on a conversion system consisting of a dynamic Rankine-type generator coupled to Klystron-type convertors.

Other things that are required are materials that are selective absorbers of solar quanta, cheap lens-like solar concentrators, and cheap automatic movements so that solar collectors can be made to follow the sun, all to make solar-collector working temperatures high enough to generate steam under pressure for conventional turbogenerators.

In addition, we need to develop photochemical reactions which can be used to produce compounds to store solar energy, compounds which can be burned or dissociated when needed. Such compounds might also be used to handle and transport hydrogen and oxygen in solid or liquid forms more conveniently.

A great deal of work has been done on the use of the sun and acreage to produce, through photosynthesis, wood and other vegetation which can be used as fuel directly or as a source of alcohols (liquid fuel). More combustible material can probably be made with the same acreage, if a photochemical reaction more rapid and more efficient than photosynthesis is used. Selected chemicals in solution exposed to the sun in solar ponds to form solid precipitates are envisaged.

Government Support Crucial

Work directed toward systems such as these will be extremely expensive and obviously cannot be expected to be supported through profit motivation alone. It simply must be supported by the governments of the world, just as atomic energy was, as a result of long-range visionary planning.

The problem before us today, therefore, is to promote awareness of the ultimate need for solar energy and to enlist the assistance of those who are in a position to allocate funds and facilities for the support of the large amount of research that must be done to prepare for this solar era.

Energy Studies in Progress

Because the U. S. government has already become very seriously concerned about the energy picture of the immediate future, as a result of certain local shortages of coal and natural gas, power brownouts, nuclear-power-plant delays, etc., there are several energy studies that are now underway or proposed by various agencies of the government. These are:

McCracken Fuels Committee. The McCracken[2] Committee study, which is being made for the executive office of the president, will report on a large number of specific items: nuclear fast-breeder reactors, nuclear stimulation of gas reserves, other means of improving gas reserves and supply, SO_2 removal technology, naval petroleum reserves policy, ways to stimulate coal production, stimulation of oil recovery, oil and gas leasing on the outer continental shelf, the Alaska oil pipeline, coal gasification, oil shale, oil from urban refuse, and geothermal steam—not a word about solar energy.

Department of the Interior Studies. Three energy studies are being made under the auspices of the Department of the Interior. One is an in-house study and another is the U. S. energy outlook study which is being made by the National Petroleum Council. The other is the National Energy Policy Study which is being made by a committee of business representatives under the chairmanship of Dr. John J. McKetta of the University of Texas.

[2] Dr. Paul W. McCracken is chairman of the Council of Economic Advisers.

Bills in Congress. In addition to these studies already in progress, the Senate has favorably reported out of committee a resolution, Resolution 45, which empowers the Committee on Interior and Insular Affairs, in cooperation with several other agencies of the government, to make a *major* energy study to be completed in 18 months. This resolution, sponsored by Senators Randolph (D-W. Va.) and Jackson (D-Wash.), is a substitute for the National Fuels and Energy Commission policy review which failed to pass in the last Congress.

The proponents of Resolution 45 have urged that a highly qualified staff be obtained to make this study, and Senator Jackson has suggested that it be directed by S. David Freeman, who was the director of the energy policy staff in the president's Office of Science and Technology. This office is continuously studying energy supply and policy matters and has contributed materially to the McCracken Committee work.

House bill HR-258 and others similar to it propose the establishment of a commission on fuels and energy. This is a reintroduction of the proposal that was covered by S.4092 which died in committee last year. There has been no action yet on this measure.

Another study of interest is that which is being made for the National Science Foundation on the "Growth and Demand for Energy" by the Rand Corp. The National Science Foundation is also sponsoring a study on "Environment and Technology Assessment" by the Oak Ridge National Laboratory.

Through participation in studies of this kind and through participation in congressional hearings on the subject, we should take advantage of every opportunity to see that solar energy is not overlooked.

Another timely opportunity to promote research and development work in the field presents itself as a result of the cutbacks that are now occurring in defense, aerospace, and nuclear-energy research. These cutbacks are releasing not only a large number of scientists and engineers, but also a large number of research facilities that are already admirably suited to do some of the sophisticated work that is required in the solar energy field.

So far, except for the support of the work that has been done on solar cells, thermionics, and thermoelectric devices for the space and defense agencies, the amount of money that has been allocated to solar research has been negligible.

What is needed, of course, is an "Office of Solar Energy Research" like the Office of Coal Research, or better yet, a "Solar Energy Commission" like the Atomic Energy Commission.

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