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# Large-Scale Industrial Applications of Solar Energy

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# LARGE-SCALE INDUSTRIAL APPLICATIONS OF SOLAR ENERGY*

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## Introduction

Research on solar energy sponsored by the U.S. Research and Development Administration (ERDA), at the Lawrence Livermore Laboratory, has concentrated on finding and developing techniques that can be made economically competitive with fossil fuels and can be applied by industry on a large scale. The difficulty lies in making solar energy competitive, not in identifying large-scale application. Table 1 suggests the widespread need for large-scale applications.

**Table 1**

1973 Energy Consumption Patterns (in per cent of U.S. total)[1]

| | Space heat and cool | Other heat and cool | Electricity | Motive | Other[a] | All uses |
|---|---|---|---|---|---|---|
| Residential | 10 | 2 | 8 | – | – | 20% |
| Commercial | 7 | 1 | 5 | – | 2 | 15% |
| Industrial | 2 | 25 | 10 | – | 4 | 41% |
| Transportation | – | – | – | 24 | – | 24% |
| All users | 19% | 28% | 23% | 24% | 6% | 100% |

[a] "Other" includes petrochemicals, asphalt, lubrication, etc.

In light of our interest in short-time scales and in the potential for large-scale application, the large fraction of total energy consumed by industry for purposes other than space heating and cooling is a particularly attractive area for research and development. Specifically, about 17% of the total energy used in the U.S. goes to produce hot water and steam for industrial processes.[2] This is equivalent to the consumption of 2.5 billion barrels (bbls) of oil each year. If solar heating could provide even 5 percent of this energy, the saving would be the equivalent of 125 million barrels of oil per year.

## The ERDA-Sohio Project

A first step is now being taken toward the large-scale application of solar energy for industrial-process heat. Under a no-funds-exchanged contract between the Sohio Petroleum Company and the U.S. Energy Research & Development Administration (ERDA), Lawrence Livermore Laboratory (LLL) is designing an experimental solar water-heating facility for Sohio to build at its new uranium mining and milling plant near Grants, New Mexico. This is scheduled to go into operation in 1976.

Hot water is used to accelerate the chemical leaching process by which the uranium ore is concentrated to yellowcake ($U_3O_8$). The plant will have oil-burning boilers to heat water, but, because of the high cost of fuel oil and the possibility of occasional shortages, Sohio would like to be able to supplement oil heating with solar heating.

For this application, we are designing a system of shallow solar ponds, which meets our basic criteria of simplicity, low cost, and early application.

A shallow solar pond is a simple, nonconcentrating solar collector similar in principle to a greenhouse. As presently conceived, each pond module is a long, narrow, clear plastic bag (200 ft by 12 ft) containing slowly flowing water 2 to 4 inches deep. The bag prevents evaporation; under it is a layer of black plastic to absorb the sun's heat, and under the black layer is a layer of insulation to minimize the loss of heat into the ground. Heating is enhanced through a greenhouse effect obtained by arching another layer or two of clear plastic over the water bag. On sunny days, hot water can be used directly from the ponds; storage reservoirs can be constructed underground to retain useful quantities of heat overnight or through cloudy periods of a few days.

The Sohio plant will require about 500 gallons per minute (gpm) of 149°F water, 24 hours a day. The water will come from local wells at about 60°F. Thus the total requirement for process heat at the plant is

$$(500 \text{ gpm}) \times (1440 \text{ min/day}) \times (8.35 \text{ lb/gal}) \times (1 \text{ Btu/lb-}^\circ\text{F}) \times (80^\circ\text{F})$$

$$= 4.8 \times 10^8 \text{ Btu/day} = 480 \text{ MBtu/day}$$

$$\approx 1.75 \times 10^5 \text{ MBtu/yr}$$

Fuel oil contains 5.8 MBtu/bbl. If it is converted to usable heat with 75 per cent efficiency, the annual consumption of fuel oil for process heat at the Grants plant will be

$$\frac{1.75 \times 10^5}{5.8 \times 0.75} \approx 40{,}000 \text{ bbl}$$

With oil at a site-delivered price of about \$14.70/bbl, this amounts to an annual fuel bill (including amortization and operation and maintenance costs for the boilers) of about \$616,000 if oil alone is used as a source of process heat.

The solar-pond facility is planned to provide about 80% of the required process heat during the summer and about 25 percent during the winter, for a year-round average of 50-55 percent. Assuming an average summer solar radiation of about 2500 Btu/day-ft$^2$ on a horizontal surface, and a summertime collection efficiency of about 60 percent, the area of a pond that will deliver 80 percent of the heat requirement is

$$\frac{(4.8 \times 10^8 \text{ Btu/day}) \times 0.80}{(2500 \text{ Btu/day-ft}^2) \times 0.60} \approx 2.6 \times 10^5 \text{ ft}^2 \approx 6 \text{ acres}$$

This corresponds to 112 modules having effective dimensions of 200 by 11.5 ft. Including service roads and curbings for the pond modules, the whole facility will occupy about 10 acres of land (Fig. 1).

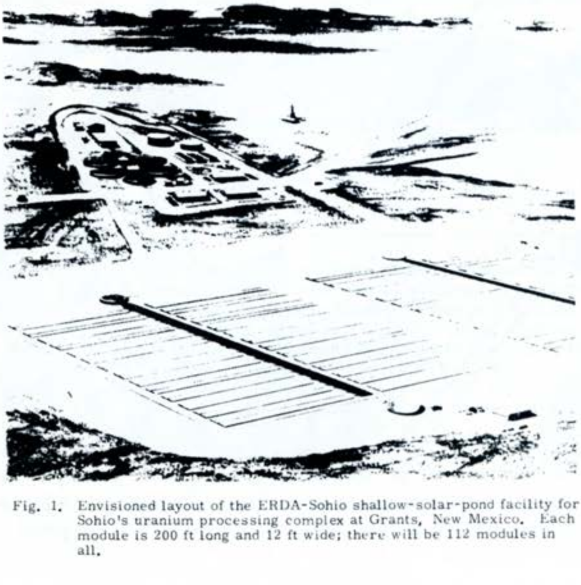

Fig. 1. Envisioned layout of the ERDA-Sohio shallow-solar-pond facility for Sohio's uranium processing complex at Grants, New Mexico. Each module is 200 ft long and 12 ft wide; there will be 112 modules in all.

We estimate that this system will collect about $10^5$ MBtu of solar energy in a year, or somewhat more than half of the total process heat needed annually. By supplementing the conventional boilers to this extent, the solar ponds should reduce the amount of oil that would otherwise be consumed at the Grants plant by about 20,000 bbl/yr, half the total requirement.

Our goal for the cost effectiveness of this first industrial application of solar heating is that it provide energy at an overall cost less than the cost of using fuel oil alone. For the first full-scale experiments, we have prepared two pond designs, one aimed at low initial cost and the other at long life (Fig. 2). The estimated installed costs of these designs, including plumbing, controls, and storage reservoirs, are $1.85/ft$^2$ and $2.25/ft$^2$, respectively. Over a period of about 10 years, however, the overall costs per unit energy delivered would tend to even out because the "low-initial-cost" design would incur higher maintenance costs -- for example, the plastic bag would have to be replaced every two or three years. We estimate that, with either design, the cost of heating water for the Grants operation, with half of the energy provided by a solar-pond facility, will be about $100,000 per year less than the cost of heating with oil only.

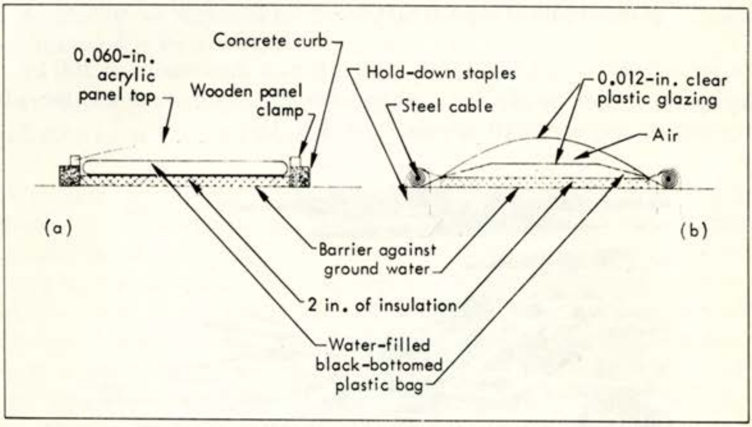


Fig. 2. Cross sections of two shallow-solar-pond designs. The "long-life" design (a) consists of the water-filled plastic bag with a separate semirigid acrylic top held in place by the wooden clamps on the concrete curb. This is the design shown in Fig. 1. The "low-initial-cost" design (b) consists of a two-compartment plastic bag. The lower compartment contains the water and the upper is filled with air to create an arc. The entire bag is anchored by cables that have been stapled to the ground.

These estimates need to be substantiated by more concrete information. for example, we have to determine experimentally which design is the more efficient heat collector and which stands up better in bad weather.

To obtain such information, we are building a prototype system at the Grants site, comprising three full-scale pond modules: two of the *low-initial-cost* design and one of the *long-life* design. One of the former will be used as a control while elements of the other are varied one at a time to determine their individual effects; it is expected that the parametric data so obtained will apply to both designs.

The complete facility is planned to go into operation in the fall of 1976, along with the rest of the plant. We will monitor the performance of this solar facility for several years to evaluate its efficiency and cost effectiveness; all information developed during this project will be published in the open literature and otherwise made available to the public.

Some idea of the cost effectiveness of solar ponds is already available, from calculational parametric studies and from observations of small experimental ponds at Livermore (Fig. 3). For the specific Sohio application, we calculate that it would still be cost effective to supply part of the process heat with solar ponds even if the cost of oil were to drop to \$6/bbl or if the cost of the ponds were to go as high as \$3.40/ft$^2$.

These conclusions need to be verified by long-term experience in operating and maintaining ponds, and this experience will be provided by the Sohio project

Fig. 3. Experimental shallow solar pond under construction at Livermore. The pond is one-quarter the length of a normal module, but it provides enough information on incident solar radiation and heat collection to permit extensive calculations.

## Future Applications

A primary goal of this ERDA-sponsored work on solar ponds is to reduce the cost of the ponds to make them even more attractive for industrial use. Several other applications are possible and will be investigated as the work progresses. For example, fossil fuel is used every autumn for crop drying. In its place, hot water from solar ponds could be converted to hot air by a heat exchanger, or the ponds might be designed to produce solar-heated air directly. Another potential use for energy supplied by shallow solar ponds is to provide hot water, space heating, and air conditioning for a residential complex.

Looking further into the future, we believe that it may be possible to make steam economically with solar energy. This would open a whole new area for supplying industrial-process heat with solar energy. Determining the feasibility of these and other applications is the objective of our ERDA program.

## Literature Cited

1. Based on *Patterns of Energy Consumption in the United States,* Stanford Research Institute (January 1972). The 1968 base data given by SRI have been projected to 1973 by applying historical growth rates.

2. *Study of Effectivenes of Industrial Fuel Utilization* (prepared for the Ford Foundation Energy Policy Project), Thermo Electron Corporation, Waltham, Mass., Rept. TE5357-71-74 (1974).

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## Legislature Sees Light

The 1974 Iowa Legislature included,in an appropriation bill, $300,000for a solar energy plant to partly heat and cool the State Capitol.

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## Solar Energy Society of America

The Solar Energy Society of America and its publication *Energies* is dedicated to a broad scope of information and education in solar energy and related energy concerns and realities. The society is working in areas ranging from the immediate use of solar energy for heating and cooling to planning preparation of lifestyles resulting from changed physical and human energy use patterns. Cost is $12.50 for subscribing memberships and $8.50 for student memberships. For information contact Solar Energy Society of America, P.O. Box 4264, Torrance, California 90510.