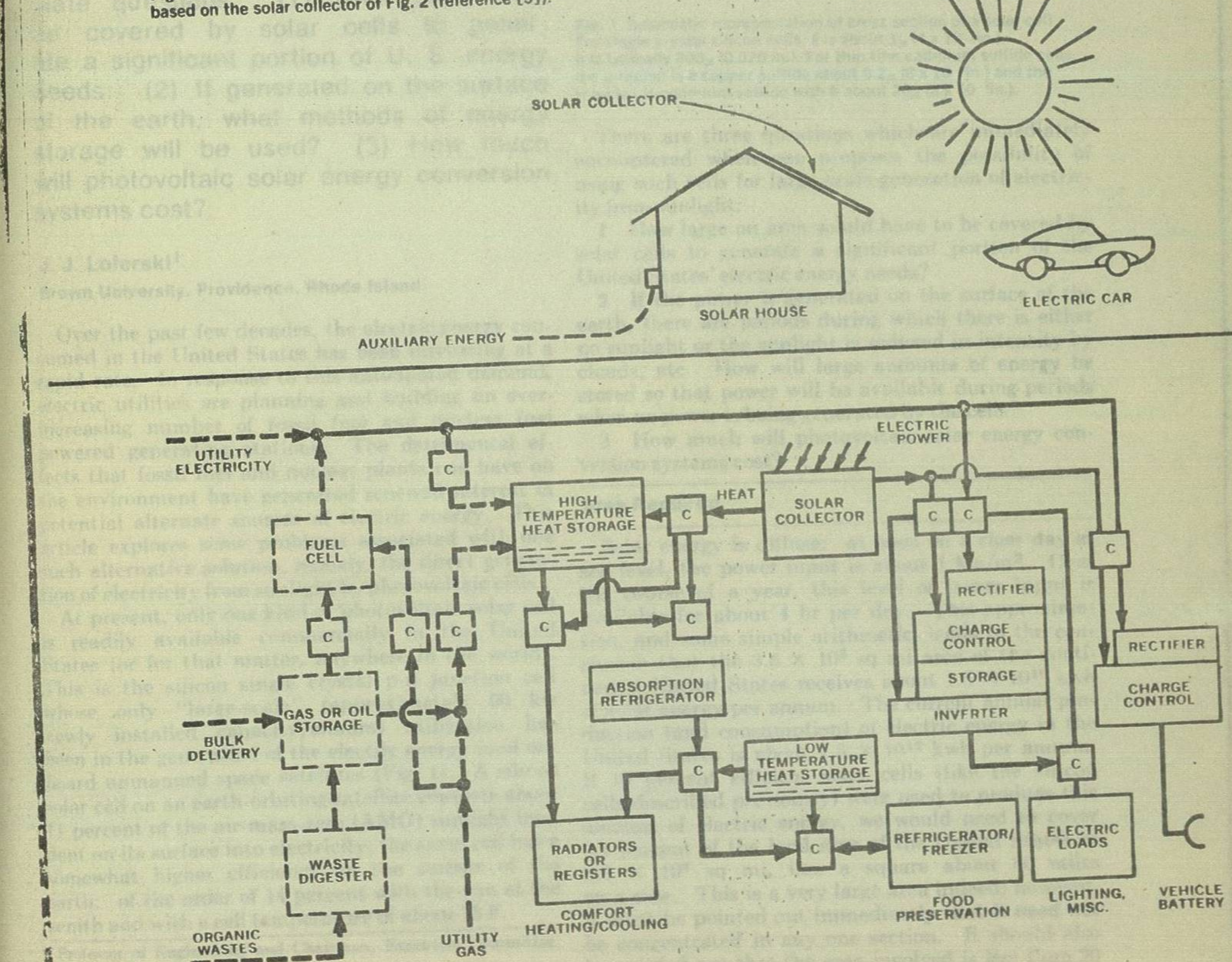
large-scale solar power photovoltaic

Fig. 3 Schematic of solar energy system for residential building based on the solar collector of Fig. 2 (reference [5]).



via the effect

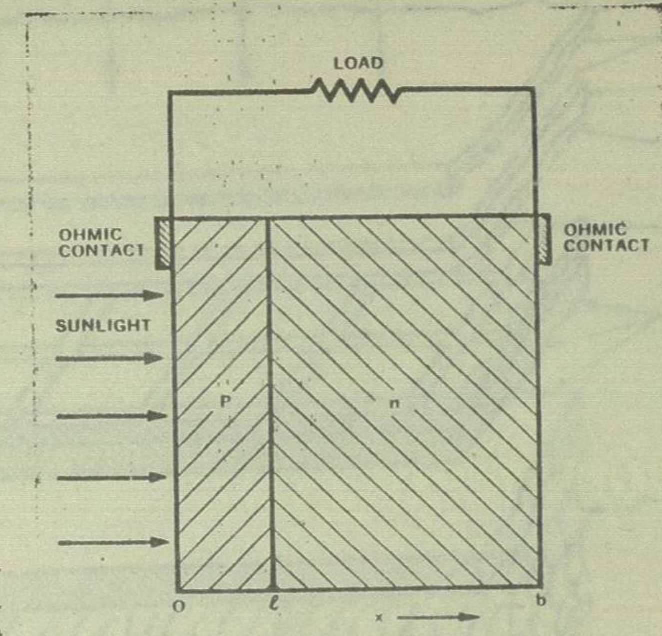


Fig. 1 Schematic representation of cross section of a solar cell. For single crystal silicon cells, ℓ is about 1μ (4×10^{-5} in.), b is typically 800μ (0.020 in.). For thin film cadmium sulfide cells, the p-region is a copper sulfide about 0.2μ (8×10^{-6} in.) and the n-region is cadmium sulfide with b about 20μ (8×10^{-4} in.).

Power via solar energy is moving inexorably toward center stage. Three immediate questions: (1) what area must be covered by solar cells to generate a significant portion of U. S. energy needs. (2) If generated on the surface of the earth, what methods of energy storage will be used? (3) How much will photovoltaic solar energy conversion systems cost?

J. J. Loferski[1]
Brown University, Providence, Rhode Island

Over the past few decades, the electric energy consumed in the United States has been increasing at a rapid rate. In response to this anticipated demand, electric utilities are planning and building an ever-increasing number of fossil fuel and nuclear fuel powered generating stations. The detrimental effects that fossil fuel and nuclear plants can have on the environment have generated renewed interest in potential alternate sources of electric energy. This article explores some problems associated with one such alternative solution, namely, the direct generation of electricity from sunlight by photovoltaic cells.

At present, only one kind of photovoltaic solar cell is readily available commercially in the United States (or for that matter, anywhere in the world). This is the silicon single crystal p-n junction cell whose only "large-scale" (approximately 50 kw newly installed capacity/annum) utilization has been in the generation of the electric energy used on-board unmanned space satellites (Fig. 1). A silicon solar cell on an earth-orbiting satellite converts about 11 percent of the air-mass-zero (AMO) sunlight incident on its surface into electricity; the same cell has a somewhat higher efficiency on the surface of the earth: of the order of 14 percent with the sun at the zenith and with a cell temperature of about 75 F.

[1] Professor of Engineering and Chairman, Executive Committee, Division of Engineering.

Based on a paper contributed by the ASME Solar Energy Division.

There are three questions which are immediately encountered when one proposes the possibility of using such cells for large-scale generation of electricity from sunlight:

1 How large an area would have to be covered by solar cells to generate a significant portion of the United States' electric energy needs?

2 If the power is generated on the surface of the earth, there are periods during which there is either no sunlight or the sunlight is reduced in intensity by clouds, etc. How will large amounts of energy be stored so that power will be available during periods when no power is being generated by the cells?

3 How much will photovoltaic solar energy conversion systems cost?

Area Required

Solar energy is diffuse: at noon on a clear day at sea level, the power input is about 1 kw/m^2. Over the course of a year, this level of power input is available for about 4 hr per day. This approximation, and some simple arithmetic, leads to the conclusion that the 3.6×10^6 sq mi area of the continental United States receives about 1.5×10^{16} kwh of solar energy per annum. The current annual production (and consumption) of electric energy in the United States is about 1.5×10^{12} kwh per annum. If 10 percent efficient solar cells (like the silicon cells described previously) were used to produce this amount of electric energy, we would need to cover 0.1 percent of the land area of the United States or 3.6×10^4 sq mi, i.e., a square about 60 miles on a side. This is a very large area indeed; however, it must be pointed out immediately that it need not be concentrated in any one section. It should also be pointed out that the area involved is less than 20 percent of the roof area of all man-made structures

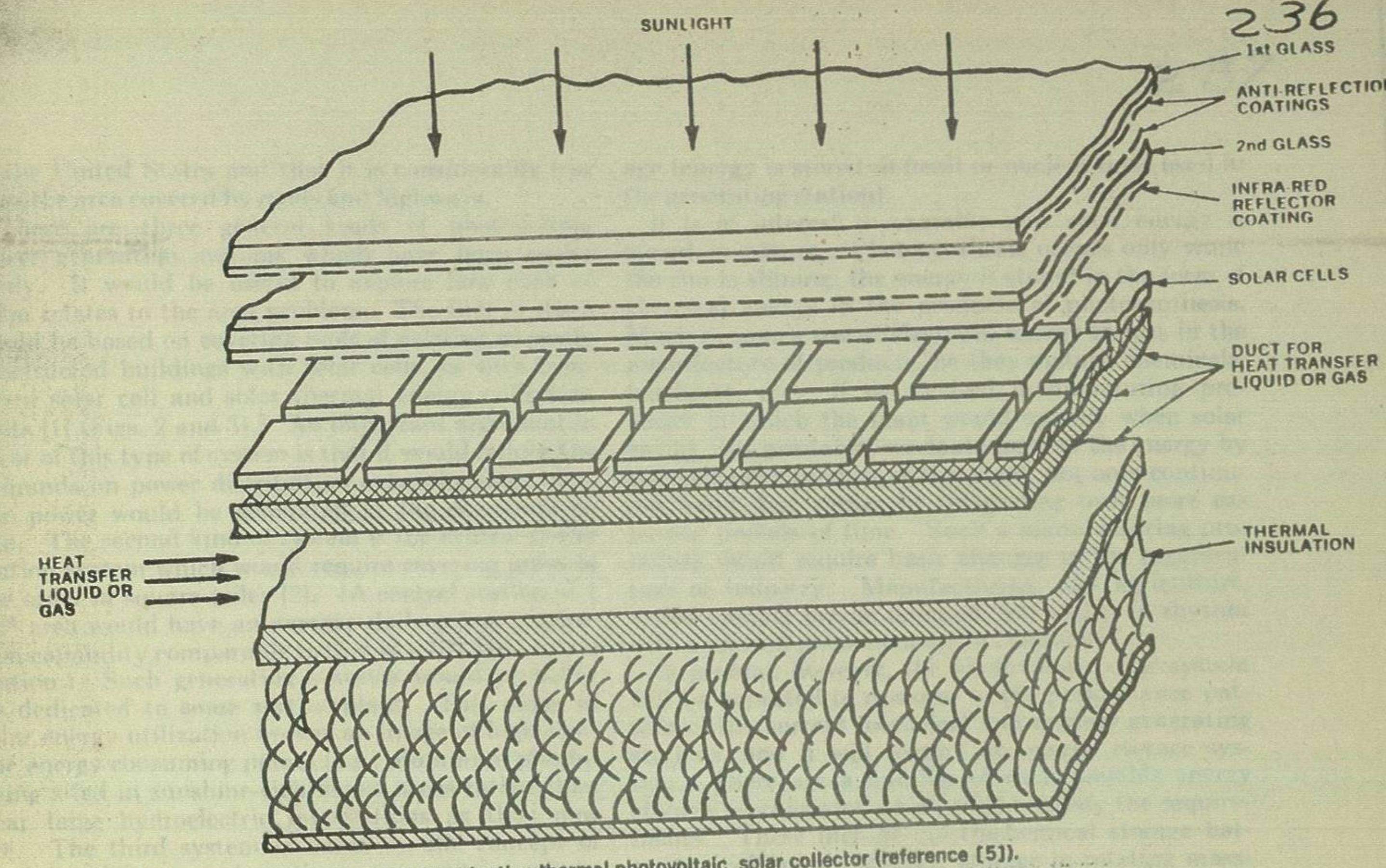


Fig. 2 Proposed structure of combination thermal photovoltaic solar collector (reference [5]).

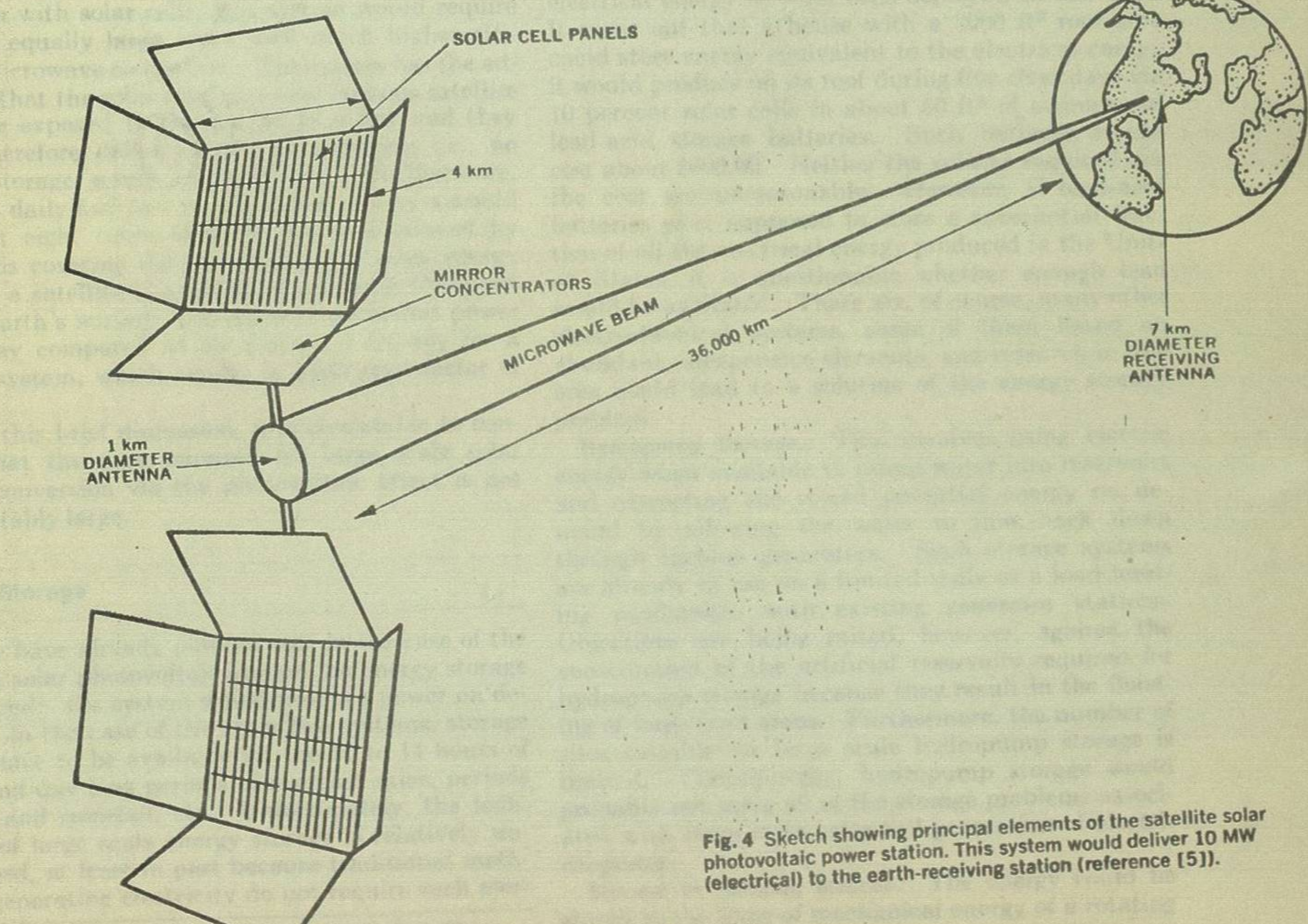


Fig. 4 Sketch showing principal elements of the satellite solar photovoltaic power station. This system would deliver 10 MW (electrical) to the earth-receiving station (reference [5]).