A Golden Thread
Years of Solar Architecture and Technology
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Postwar Energy Perspectives

For almost three decades, problems of energy, from oil to natural gas from the surface, easy to sell their oil to America, also helped to keep oil companies to discovering and drill. could also be dedicated price of oil below. Natural gas price was same period. Often same tax advantages, government regulation of much more accessible.

The falling price and availability of supplies, did natural gas rise, production situation would come. Since 1954, "The industry in the United States is in a product."

With fuel appeared to meet growing power procure the need. After World War II, efficiency increase in the costs of building quickly if their customers hoped that people electric company runs as you could. They explained, "If you sell gas.

Both gas and electric campaigns and preferential promotional campaigns and regional electric utility thereby use more stimulated consumers kilowatt-hour if they used more than 750 kilowatt-hour. The fuel used the "Blue Flag."

The energy company desire to "Live Better, house heating, warm"
For almost three decades after the end of World War II, the United States had few problems of energy supply. Its industry, commerce and homes all had ready access to oil and gas from both domestic and foreign sources. Most of the oil was close to the surface, easy to tap, and therefore economical to extract. Foreign governments sold their oil to American companies at extremely low prices. The U.S. government also helped to keep oil prices low and profits high. Depletion allowances permitted oil companies to write off a portion of their income taxes against the cost of discovering and drilling for oil in the United States. Royalty payments on foreign oil could also be deducted. These and other government subsidies helped to keep the price of oil below $3 a barrel during the late 1950's and throughout the 1960's. Natural gas prices were low, too—below $1 per thousand cubic feet during this same period. Often obtained as a by-product of oil exploration, gas enjoyed the same tax advantages as oil. The cost of natural gas was also kept down by government regulation of gas prices and by improved pipeline networks that made supplies much more accessible.

The falling prices of fossil fuels during this period also reflected the growing availability of supply. Crude oil reserves rose steadily between 1952 and 1964, as did natural gas reserves. Corporate spokesmen assured the public that this rosy situation would continue almost indefinitely. As one gas company executive stated in 1954, "The industry discovers more gas every day than is consumed every day in the United States. I don't think in our lifetime we will see the depletion of our product."

With fuel apparently so abundant and cheap, electric companies began to expand to meet growing postwar demands. Liberal government policies made it easy to procure the needed capital to build larger and more efficient power plants. Soon after World War II the electric rates plunged as consumption grew and power plant efficiency increased. The electric utilities encouraged greater consumption because the costs of building new plants and installing electric lines could be recovered more quickly if their customers used more electricity. "Once you had the lines in, you hoped that people would use as much electricity as possible," an executive for one electric company remarked. "You wanted to get as much return on your investment as you could. The gas companies had a similar objective. As one employee explained, "If you sell more you make more."

Both gas and electric utilities promoted consumption through advertising campaigns and preferential rate structures. "The Gold Medallion Program," a national promotional campaign conceived by General Electric and later taken over by regional electric utilities, urged Americans to buy more electric appliances—and thereby use more electricity. Lower rates for increased use of electricity also stimulated consumption. During the 1960's many U.S. families paid about 4¢ per kilowatt-hour if they used 100 kilowatts or less per month, but the rate fell to 2¢ if more than 750 kilowatt-hours were used. In some areas, people paid less than 2¢ per kilowatt-hour. The gas companies had similar rate structures that made it cheaper to use more gas. They also launched their own pro-consumption campaign, which used the "Blue Flame" as its slogan and symbol.

The energy companies' publicity and the enticement of lower prices worked. A desire to "Live Better Electrically" led families to opt for homes with electric house heating, water heating, ovens and many other appliances. A growing
afluenza that allowed people to indulge their appetite for new electric appliances, combined with the postwar baby boom, helped increase electricity generation by over 500 percent between 1945 and 1968. Natural gas consumption also zoomed upwards as gas heating and conveniences such as clothes dryers became more popular. Natural gas production more than doubled—from 6 to 16 trillion cubic feet—between 1950 and 1965. U.S. fuel consumption as a whole more than doubled between 1945 and 1970.

A Note of Caution

The frenetic pace at which America was gobbling up its energy resources alarmed only a few farsighted individuals. Eric Hodgins, editor of Fortune, called the careless burning of coal, oil and gas a terrible state of affairs, enough to "horrify even the most complaisant in the world of finance." Writing in 1953, he warned that "we live on a capital dissipation basis. We can keep this up perhaps for another 25 years before we begin to find ourselves in deepening trouble." But such warnings were generally treated with derision or merely ignored. Those predicting energy shortages were labeled pessimists. "Not many in industry wanted to hear such talk," commented Charles A. Scarlett, then editor of the Westinghouse Company's technical publications. "They were making too much money on energy sales."

The Nuclear Option

The U.S. government chose a different path. Eisenhower Administration's nuclear future. Energy experts in Washington and in the Nation's News and Business, the industry were "definitely" that the nuclear option should be considered. "We could take advantage of our lead in atomic energy dollars worth of research,"

Nuclear energy promises to provide a large, small amounts of a source of energy. Its development, and many...
A few scientists and engineers took the same dim view as Hodgins and sought an alternative to the fuel crisis they saw was inevitable. In 1955, they founded the Association for Applied Solar Energy Research and held the World Symposium on Applied Solar Energy in Phoenix, Arizona. Delegates from all over the world attended, presenting research papers and exhibiting solar devices. Israel displayed its commercial solar water heaters, and representatives from Australia and Japan discussed their nations’ increasing use of the sun. To many, the Symposium represented the dawn of a new solar age. But the careless confidence of energy-rich America squelched the hope in that country. Solar energy received virtually no support in the ensuing years, and by 1963 the Association found itself bankrupt. “They couldn’t even pay my final salary,” noted Scarlett, then editor of its publications.

Whereas the governments of Israel, Australia and Japan deliberately aided the solar industry, the U.S. Congress and the White House were sitting on the sidelines while the hopes of a prescient few floundered. True, as early as 1952 the President’s Materials Commission appointed by Harry S. Truman came out with a report, “Resources for Freedom,” predicting that America and its allies would be short of fossil fuels by 1975. This report urged that solar energy be developed as a replacement. “Efforts made to date to harness solar energy are infinitesimal,” the commission chided, despite the fact that “the United States could make an immense contribution to the welfare of the free world” by exploiting this inexhaustible supply. The commission predicted that, given the will to go solar, there could be 13 million solar-heated homes in the nation by the mid-1970’s. However, Washington did not heed this advice in the years that followed. Federally funded scientific research had a multi-billion dollar budget, but the amount allocated to solar energy projects was only a tiny fraction of one percent.

The Nuclear Genie

The U.S. government admitted the very real possibility of an energy crisis. But it chose a different solution—the atom. Beginning in the early 1950’s with the Eisenhower Administration, nuclear power was seen as the energy source of the future. Energy equipment manufacturers and utility companies took their cue from Washington and jumped into nuclear development. According to a 1954 article in U.S. News and World Report, the huge corporations involved in the new nuclear industry were “backed by great capital resources and staffed with scientists,” and could take advantage of “the knowledge already acquired by 14 years and 10 billion dollars worth of federal research.”

Nuclear energy appeared to offer tremendous power in exchange for relatively small amounts of fuel and labor. Scientists and the general public alike shared this belief, and many people around the globe were infected by America’s enthusiasm. At an international conference on nuclear energy held in 1954 in Oslo, Norway, Alvin M. Weinberg, then director of Oak Ridge National Laboratory in Tennessee, reported that Europeans seemed even more excited about nuclear prospects than their American colleagues. He found them quite concerned about their import-dependent situation. Indigenous coal supplies were inadequate to meet projected energy needs over the next two decades—meaning further reliance on imported oil.
Two years later, with the Suez crisis threatening to strangle Europe's oil supply line, leaders in England and on the Continent fervently embraced nuclear energy as their savior. As *Business Week* reported, they were determined that their "industrial machine and livelihood must no longer be at the mercy of Middle Eastern politics," and even such countries as India and, ironically, Japan took up the nuclear banner—although solar water heaters were already helping thousands of Japanese save fuel at the time.

With a wave of hope for atomic power, the construction of America's first nuclear power plant began in 1954. President Eisenhower inaugurated the construction of America's first nuclear power plant with a wave of this radioactive wand.

*Left: Illustration from a 1954 article in U.S. News and World Report. A close partnership between government and industry made the dream of nuclear power a reality.*

*Right: In 1954, President Eisenhower inaugurated the construction of America's first nuclear power plant with a wave of this radioactive wand.*

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How the atom is putting new shapes on the horizon

Meanwhile America’s nuclear program was rapidly advancing. It had the blessings of President Dwight D. Eisenhower, who preferred his own “Atoms for Peace” plan to the recommendations of Truman’s Materials Commission. The media coverage of Eisenhower’s ceremonial inauguration of America’s first commercial nuclear power plant illustrated the nation’s heady romance with the atom. In 1954, Life magazine described the event:

With a wave of a radioactive wand, President Eisenhower transformed the bright hope for atomic power peacefully used into a solid certainty. . . . Standing in the studio of Denver’s T.V. station KOA, the President slowly lowered the head of the wand over a fission counter. When the counter’s needle swung across the dial, it electrically set in motion, 1,300 miles away at the Shippingport, Pennsylvania, plant site, an automatically controlled power shovel which scooped up the first symbolic shovelful of earth.

Two years later, England opened its first commercial nuclear power plant with similar fanfare.

The entire U.S. political spectrum backed nuclear power as the dream solution to future energy problems. Government officials, industry spokesmen and nuclear scientists claimed that atomic power was a “clean, safe” energy source. It would
eliminate the air pollution inherent in oil-fired and coal-fed power plants. The only controversy was over who should own and operate the reactors—private enterprise or the government.

Only a few individuals could see that the Aladdin’s lamp of nuclear power was flawed, and fewer dared to say so. In 1956, Erich A. Farber and J.C. Reed of the College of Engineering at the University of Florida stressed that nuclear is limited "both by uranium ore supply and by the inherent hazards of radiation." George W. Russler, Chief Staff Engineer at the Minneapolis-Honeywell Research Center, analyzed the push toward nuclear power as an unfortunate choice. In an article, "Nuclear or Solar Energy," published in 1959, he commented on the waste disposal dilemma:

If one projects the problem into the future when all the world’s conventional power plants, multiplied by a factor of 23 or more, are replaced by atomic plants, then the enormity of the problem of waste disposal becomes apparent. Perhaps, on this scale, the problem may not be solvable.

Another problem was the enormous amount of energy needed to enrich uranium. According to experts cited by Russler in 1959, 10 percent of America’s electrical energy was being used to produce the nation’s output of enriched uranium—most of which was used to manufacture nuclear warheads. He questioned whether there would be any net gain in electrical production if this enriched uranium were instead used to produce electricity.

Russler contrasted the problems of nuclear energy with the attractiveness of solar energy:

Solar energy is the one major source of energy which would not require several decades of development before large energy contributions could be obtained. Its use does not involve such serious problems as the control of a critical mass, or disposal of dangerous waste products, or operating health hazards. It does not require multi-billion dollar installations, nor huge concentrations of basic materials, nor elaborate controls. Sufficient engineering know-how, as well as simple processes, are already sufficiently available to make a major start at its utilization... The only elements lacking are an appreciation of the urgency of the energy situation and a determination to get started.

Russler suggested that solar energy could make a large contribution toward heating buildings. In America, this task consumed larger quantities of fossil fuel than transportation, industrial processes, or electrical power generation. He pointed out that the low-temperature heat needed in homes and office buildings "ideally matches the low-grade heat derived from the simplest and most efficient solar energy collectors." Hence, this was the perfect way to start putting solar energy to widespread use.

The Discovery of Solar Cells

At about the same time that the first commercial nuclear power plants were being built, vastly improved photovoltaic cells were developed at Bell Telephone Labs in Murray Hill, New Jersey. These "solar cells" could transform solar energy directly into electricity. These cells were made by dissimilar metals rather than the homogenous kind.

In 1839 Edmund Fritsche, a German inventor, made a device that looked like a watch glass with a transparent metal plate that was "continuously filled with sunlight." In 1873, a similar device was introduced in the United States by Fritsche. By 1883, these cells could improve the realism of a clock by receiving sunlight and converting it to electric energy. During the next fifteen years, the power of these cells improved greatly and the performance of the devices they could power improved significantly.
nuclear power was advocated by J.C. Reed of the United States. "Nuclear is limited by imagination," George W.梅、Research Center, said in an article.

For conventional power plants, then, the focus is on the waste disposition and the attractiveness of uranium to enrich uranium. America's electrical industry, however, relies on a larger amount of uranium—most of it needed whether there was a waste or not. The energy situation and technology toward heating of fossil fuel than electricity. He pointed out "that the greatest efficiency solar heating solar energy to...

In 1839 Edmund Becquerel, a French experimental physicist, discovered that sunlight could produce electricity. Almost 50 years later Charles Fritts, an American inventor, made the first solar cells. These thin wafers—each about the size of a quarter—were made from selenium (an element derived from copper ore) covered with a transparent gold film. When sunlight struck the cells, a current was generated that was "continuous, constant, and of considerable electromotive force," according to Fritts. He believed that at least 50 percent of the light hitting the surface of these cells could be converted into electrical energy. But such a grandiose forecast proved unrealistic. He did not realize that less than one percent of the light energy hitting the selenium was actually converted into electricity, and that the mechanism for capturing this electricity was no more than 50 percent efficient.

During the next few decades, few people took any interest in trying to upgrade the performance of solar cells. Classical physics of the late nineteenth century could
not explain the photovoltaic effect, and many scientists and engineers did not give it any credence. Only after the bold new theories of quantum mechanics and relativity won general acceptance in the early twentieth century did work in solar cells begin again. Scientists now pictured an electrical current as an orderly movement of electrons which could be set into motion by direct interaction with particles of light called photons.

With these firm theoretical underpinnings, scientists began to reexamine the photovoltaic effect, and rediscovered the selenium solar cell in the early 1930's. Aside from minor design changes, this cell was almost an exact replica of the one developed by Fritts. Its reappearance renewed the dream of producing electricity commercially without fuel. However, scientists were hindered by the same limitations that Fritts had encountered earlier: the amount of electricity produced was miniscule. The rediscovery of the solar cell did lead to useful light-sensitive devices such as the photometers used in photography. But, for more than two decades the best selenium cells could convert less than one percent of all incoming sunlight into electricity—hardly enough to justify their use as a power source.

In 1954 researchers at Bell Telephone Laboratories made an accidental discovery that revolutionized solar cell technology. They were searching for a dependable alternative power source for telephone systems in rural areas. Darryl Chapin, leader of the project, thought that improved selenium cells would be the ideal solution. But efforts to develop a more efficient selenium cell failed. Meanwhile Calvin Fuller, a Bell scientist working in another department, had been studying silicon—one of the two major elements in common sand. Fuller was exploring silicon's useful photoelectric qualities and how it could convert sunlight into direct current. Meanwhile, Gordon Pearson, a Bell scientist, was surprised, a sign of the times.

Pearson knew that Fuller and he brought the two together and soon Fuller and Pearson could convert more than the equivalent of a D battery into electricity. Fuller and Pearson's breakthrough inspired people around the world to think about solar-powered radio and telephone stations. Fuller had described a solar-powered steered automatic guided vehicle, and perhaps with this technology solar cells supplying energy to almost all human activities would be possible.
silicon's usefulness in making a rectifier, a device that changes alternating current into direct current. Fuller discovered that he could increase the efficiency of the silicon rectifier by adding certain impurities. The director of Fuller's project, Gordon Pearson, happened to expose the modified silicon rectifier to light. To his surprise, a significant electric current was generated.

Pearson knew the problems Chapin had been having with the selenium cells. So he brought the discovery of silicon's light sensitivity to Chapin's attention, and soon Fuller and Chapin were busy refining a silicon solar cell. Their first design could convert 4 percent of all the incoming sunlight into electricity—five times more than the best selenium cell. Not content with this conversion ratio, they continued to work on the silicon cell for several months. By May they had produced a solar cell with an efficiency of 6 percent. News media carried pictures of Chapin, Fuller and Pearson powering a transistor radio with solar energy. The response of people around the world was tremendous. Business Week ran a futuristic article about solar-powered fans, lawn mowers, and even a solar convertible that was steered automatically so that "all the riders could sit comfortably in the back seat and perhaps watch solar-powered TV." Others rhapsodized about acres of solar cells supplying the world with cheap, nonpolluting energy.
Solar Cells at Work

Silicon solar cells have been proposed as a system in an isolated rural area providing nighttime power. The concern about the economic analysis is whether such a system remains competitive with conventional power systems.

Just as solar cells have been developed and came along, so have other related technologies. A compact and lightweight system for generating power supply the energy needs of small remote locations. The Space Administration has demonstrated a system connected to a solar cell array.

Fuller and other solar cell researchers believe that a conversion rate of 10% is 'reasonably good for it,' said Clark. He noted that such a conversion rate is not as expensive as many thought was required for solar power. The hope is to lower the conversion rate to a point where it will be less expensive to produce. Further research is needed to improve the efficiency of the component components. The challenge is to increase the output per cell while keeping costs low enough to make the system economically feasible.
Fuller and Chapin took a more sober view of the silicon cell, even after reaching a conversion ratio as high as 15 percent. "We tried to avoid making too much claim for it," said Chapin, "because we knew it was in the laboratory stage, it was an expensive process, and there was much to be done before we could speak of lots of power." The high-purity silicon required for efficient cells cost $80 a pound at the time. Furthermore, each razor-thin wafer had to be individually sliced from its component core, which hiked manufacturing costs even higher. And the power output per cell was so small that providing large amounts of electricity would be prohibitively expensive for most commercial purposes.

Solar Cells at Work

Silicon solar cells were first used as the power source for a telephone relay system in an isolated rural area of Georgia. The setup included battery storage for a nighttime power supply and worked without problems. However, Chapin's concern about the cost of solar-generated electricity proved to be well founded. An economic analysis of the solar-powered telephone system showed that it was not competitive with a system powered by conventional electricity.

Just as solar cells were about to be consigned to the curiosity heap, the space race came along. Satellites needed a long-term, autonomous power source that was compact and lightweight. Conventional fuel systems or batteries large enough to supply the energy required were too cumbersome. The National Aeronautics and Space Administration saw solar cells as the perfect answer. They did not have to be connected to a storage system because the sun shines 24 hours a day in outer space.
Hence, solar cells became a cost-effective fuel for the new solar cell industry designed for space satellites.

Back on earth, there was also support whatever the treasure hunters, though there was little indication of their future. Domesday Book of 1086 gives between 153 and 364 monasteries during that period, and the percentage of land in 1542 was 66 percent in 1544. The treasures of the future had to wait.

Despite such disinterest, and cheaper sources of energy, the interest was a sign that a new atomic power era was on the horizon, not just by seeming to conjure an aura surrounding the creature of powerful nuclear reactions that had received very mixed reviews in the concept of sun and earth.
Hence, solar cells were easily the lightest power source available, and they proved cost-effective for space applications. The U.S. space program created an entire solar cell industry. Starting in the late 1950's, solar cells powered all American space satellites from Vanguard to Skylab.

Back on earth, however, the terrestrial use of solar cells did not receive any support whatever. Fossil energy consumption continued to break records, even though there were increasing signs that severe fuel shortages loomed in the near future. Domestic oil production in the United States increased by 43 percent between 1953 and 1969, but the number of new oil discoveries fell by 43 percent during that period. America's reliance on imported oil also grew, rising from 14 percent in 1954 to 22 percent in 1965. Two years later, the size of America's crude oil reserves declined for the first time in the nation's history.

Despite such portents the government never funded research to develop better and cheaper solar cells for ordinary commercial use. Why it showed such a lack of interest was a mystery to some. As early as the mid-fifties, the New York Times suggested that the U.S. government 'ought to transfer some of [its] interest in atomic power to solar.' But Washington's attitude mirrored that of a nation hypnotized by seemingly limitless supplies of cheap fossil fuel, and by the almost magic aura surrounding nuclear energy. There was no solar lobby to counter the already powerful nuclear juggernaut. Consequently, solar cells and other solar technologies received very little support during the quarter century after World War II. The concept of sun power remained mostly within the realm of science fiction.