

A Review On History And Power From Sunshine And Storage Of It

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Abstract - This working paper provides a longitudinal perspective on the business history of solar energy between the nineteenth century and the present day. It covers early attempts to develop solar energy, the use of passive solar in architecture before World War 2, and the subsequent growth of the modern photovoltaic industry. It explores the role of entrepreneurial actors, sometimes motivated by broad social and environmental agendas, whose strategies to build viable business models proved crucially dependent on two exogenous factors: the prices of alternative conventional fuels and public policy. Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam.

Keywords- Solar Photo Voltaic, renewable energy, roof top SPV, non-conventional sources of energy, solar energy

I. INTRODUCTION

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy.

Solar energy is quite simply the energy produced directly by the sun and collected elsewhere, normally the Earth. The sun creates its energy through a thermonuclear process that converts about 650,000,000¹ tons of hydrogen to helium every second. The process creates heat and electromagnetic radiation. The heat remains in the sun and is instrumental in maintaining the thermonuclear reaction. The electromagnetic radiation (including visible light, infra-red light, and ultra-violet radiation) streams out into space in all directions.

Only a very small fraction of the total radiation produced reaches the Earth. The radiation that does reach the Earth is the indirect source of nearly every type of energy used today. The exceptions are geothermal energy, and nuclear fission and fusion. Even fossil fuels owe their origins to the sun; they were once living plants and animals whose life was dependent upon the sun.

Much of the world's required energy can be supplied directly by solar power. More still can be provided indirectly. The practicality of doing so will be examined, as well as the benefits and drawbacks. In addition, the uses solar energy is currently applied to will be noted.

Methods of collecting and storing solar energy vary depending on the uses planned for the solar generator. In general, there are three types of collectors and many forms of storage units.

The three types of collectors are flat-plate collectors, focusing collectors, and passive collectors.

Flat-plate collectors are the more commonly used type of collector today. They are arrays of solar panels arranged in a simple plane. They can be of nearly any size, and have an output that is directly related to a few variables including

Size, facing, and cleanliness. These variables all affect the amount of radiation that falls on the collector. Often these collector panels have automated machinery that keeps them facing the sun. The additional energy they take in due to the correction of facing more than compensates for the energy needed to drive the extra machinery.

Among the renewable resources, only in solar power do we find the potential for an energy source capable of supplying more energy than is used.⁵

Suppose that of the 4.5×10^{17} kWh per annum that is used by the earth to evaporate water from the oceans we were to acquire just 0.1% or 4.5×10^{14} kWh per annum. Dividing by the hours in the year gives a continuous yield of 2.90×10^{10} kW. This would supply 2.4 kW to 12.1 billion people.⁶

This translates to roughly the amount of energy used today by the average American available to over twelve billion people. Since this is greater than the estimated carrying capacity of the Earth, this would be enough energy to supply the entire planet regardless of the population.

Unfortunately, at this scale, the production of solar energy would have some unpredictable negative environmental effects. If all the solar collectors were placed in one or just a few areas, they would probably have large effects on the local environment, and possibly have large effects on the world environment. Everything from changes in local rain conditions to another Ice Age has been predicted as a result of producing solar energy on this scale.

Of all the energy sources available, solar has perhaps the most promise. Numerically, it is capable of producing the raw power required to satisfy the entire planet's energy needs. Environmentally, it is one of the least destructive of all the sources of energy. Practically, it can be adjusted to power nearly everything except transportation with very little adjustment, and even transportation with some modest modifications to the current general system of travel. Clearly, solar energy is a resource of the future.

II THE PHOTOVOLTAIC CELL AND THE NEW SOLAR INDUSTRY IN THE UNITED STATES

The solar industry was re-invented through the development of the photovoltaic cell (hereafter PV). PV cells converted solar radiation directly into electricity. When photons of sunlight strike the cell, electrons are knocked free from silicon atoms and are drawn off by a grid of metal conductors, yielding a flow of direct current. It was, at least potentially, a dream technology. An article in Science magazine noted:

“If there is a dream solar technology it is probably photovoltaic’s – solar cells...They have no moving parts and are consequently quiet, extremely reliable, and easy to operate. Photovoltaic cells are a space age electronic marvel, at once the most sophisticated solar technology and the simplest, most environmentally benign source of electricity yet conceived.”

The new technology had its origins in the postwar United States. The story began at Bell Laboratories, the research facility of AT&T which was famously responsible for inventing television, lasers and transistors, and much else.³⁶ Russell Ohl’s invention of the silicon solar battery in 1946 was a key breakthrough. Ohl, who had joined Bell Laboratories in 1927, was a physicist whose specialized area of research was the behavior of crystals. In 1939 Ohl discovered the PN barrier “P–N junction”. There was little known about the impurities within crystals, but Ohl discovered the mechanism by which it worked. It was the impurities which made some sections more resistant to electrical flow than others, and thus it was the “barrier” between these areas of different purity that made the crystal work. Ohl later found that super-purifying germanium was the key to making repeatable and usable semiconductor material for diodes. His work with diodes led him later to develop the first silicon solar cell, and in 1946 he filed a US patent for a “Light sensitive device”.

In 1954 other Bell Laboratory scientists invented the first PV cell which could produce significant electric power. Daryl Chaplin had joined Bell labs in 1930, and in the early 1950s began working on finding new sources of power for transistor telephones. This led to experiments with converting solar energy into electrical energy. Chaplin, and fellow scientists Gerald Pearson and Calvin Fuller, used strips of silicon placed in sunlight to capture free electrons and turn them into sunlight. Their public demonstration of the cell inspired a 1954 New York Times article to predict that solar cells would eventually lead “to the realization of one of mankind’s most cherished dreams -- the harnessing of the almost limitless energy of the sun.”³⁸The silicon photovoltaic invention by Bell Labs came to the attention of the recently created US space program. PV solar cells appeared as potential solution to power those satellites.

The Bell PV solar cell coincided with a renewal of interest in solar energy more generally. In 1953 a multi-volume report to the U.S. President by W.S. Paley on “Resources for Freedom” had made the case that fossil fuels seemed to be in declining supply. This stimulated the formation of an Association for Applied Solar Energy in 1954. In November of the following year it organized two conferences, one on the scientific basis of solar energy in Tuscon, followed by a World Symposium on Applied Solar Energy in Phoenix. These meetings attracted delegates from 37 countries, and

Bell’s PV cell was exhibited. The Association energetically pursued new prospects for solar energy. In 1957 it held an International Architectural Solar House Competition which attracted more than 1,000 architects from 36 countries. The winning design was never built.

2.1 SEARCHING FOR SCALE

The rise of Federal and state government investment in solar energy prompted the entry of new entrepreneurial actors in the United States interested in transitioning the industry from the space program to new markets on earth. This turned out to be an expensive proposition, both in terms of capital and in terms of the time taken to develop technologies. Much earlier than in wind energy, entrepreneurs in solar found themselves turning to big corporations. The results were mixed. In the United States, oil companies emerged as key investors. There were multiple motivations, but initially one stood out: solar was a potential solution to a specific operational problem of powering offshore platforms. By 1980, solar powered navigation systems were installed in all production platforms in the Gulf of Mexico. At that date, oil companies accounted for 70 per cent of all the solar modules sold in the United States. Table 1 lists the major US oil company investments in solar during these decades.

Table 1 Major U.S. Oil Company Investments in Solar Energy 1970-1980

Date	Firm	Strategy	Outcome
1973	Exxon	Creates Solar Power	Sold to Solarex in 1984
1974	Mobil	Joint Venture with Tyco	Sold to ASE 1994
1977	Arco	Acquires Solar Power	Sold to Siemens 1990
1979	Amoco	Invests in Solarex (100% in 1983)	Amoco acquired by BP 1999

These large investments from oil companies began with the activities of Elliot Berman, a New Jersey-based industrial chemist. In 1972 Berman developed a new, cheaper type of solar cell based on organic materials such as dyes. During the 1960s Berman had worked for the Itek Corporation, a US defense contractor which made cameras for spy satellites. Itek was, like many companies at the time, concerned to diversify its business, and Berman successfully facilitated their entry into the photographic materials business. In 1968 the firm invited Berman to consider new businesses, and he determined that he wanted to develop products which had a major social impact. He identified a correlation between “energy availability and quality of life,” and began to consider ways to provide electrical power for the rural poor in developing countries. He found the solution in the promise of solar energy. In view of the high cost of silicon cells, he suggested that the company needed to invest in a new type of solar cell, made from the photographic film

on which he had worked. Itek did not proceed with the project.

Berman left his company, and spent six months attempting to interest venture capitalists and others in his proposed solar project. After eighteen months a chance conversation led Berman to Exxon, which had just begun to consider looking at alternative energies in the 23 expectation that conventional energy prices would raise substantially over the following decades. Berman moved his lab into the oil company, and started developing this new technology. The organic cells he was proposing would take years to develop, in the meantime, he decided to buy conventional silicon solar cells with which he commercialized an interim product.⁶⁸ Berman first tried to purchase these cells from a small company named Centralia, but all the company had to sell were rejects from the space program which was far from enough to meet his needs. He then decided to fly to Japan, to meet with the Japanese company Sharp, which had been producing solar cells for over a decade. Berman and Sharp could not agree on a price, and no agreement was reached. Berman realized he needed to manufacture these silicon solar cells himself. In April 1973, he launched Solar Power Corporation, a fully owned subsidiary of Exxon. This was the first company established to specifically manufacture terrestrial PV cells in the U.S. Berman did not use the expensive pure semiconductor-grade crystalline silicon employed in the space industry, but instead cheaper silicon wafers rejected by the semiconductor industry. First introduced to supply power to remote locations (telecommunications, coast guard etc), it was intended in the long run compete with conventional power sources.

Berman initially believed that the US Coast Guard would be the initial primary customer. However the Coast Guard, noting the diversity of geographical conditions it faced, declined to commit.⁷¹ Instead, Berman started manufacturing solar cells to be used on Exxon's off-shore platform in the Gulf of Mexico. According to Berman "We went and visited some Exxon platform in the gulf. What we learned, which everybody down there knew, but nobody at the headquarters knew, is you have one platform that's loaded with power, and that's where all the crews live. However, most of the platforms are unmanned and have no power. At the time, the 24 system for powering platforms relied on large lead-acid batteries, each weighting several hundred pounds and costing over \$2,100 each. When exhausted the crew would simply dispose of the batteries in the waters, which had a devastating effect on marine life. In 1978, the Environmental Protection Agency outlawed such disposing of batteries in the ocean, which added a sense of urgency for oil companies to come up with a new way to power their platforms.

A second large US oil company to invest in solar was Mobil. As in the case of Exxon, the origins of their involvement lay in an entrepreneur outside the company. During the 1960s a researcher called Abraham Mlavsky, working with an investment and holding company called Tyco in Waltham, Massachusetts, engaged in semiconductors and energy conversion, developed the process for producing a continuous thin ribbon of silicon that could be separated into suitable lengths, processed into solar cells, and placed in modules. Tyco had developed the technology for growing sapphire tubes for sodium vapor lamps and other products but silicon was a much more

difficult material to work with, as temperatures had to be extremely tightly controlled for the silicon to grow continuously. In 1971 NASA, in search of lighter weight solar cells, gave the firm the chance to produce solar cells from ribbon silicon, but were unable to achieve suitable conversion efficiencies. NASA resumed interest two years later, and in 1974 Mobil and Tyco joined forces to begin developing advanced silicon solar cells. Mobil-Tyco spent years attempting to develop efficient production, but by the end of the 1980s they had cut the cost of fabricating crystalline silicon solar cells in half. During the early 1990s a plan was developed to make and sell solar cells to utilities in the desert regions of the western United States to help power residential air-conditioning, but a sharp fall in natural gas prices led to Mobil to divest altogether by selling to the German company ASE.

The entry of Arco, a third US oil company, into solar came through the activities of Joseph Lindmeyer and Peter Varadi. Both were working on space solar cells in the early 1970s for a satellite company called the Communications Satellite Corporation (COMSAT). While at COMSAT, Lindmeyer developed a photovoltaic cell that was 50 per cent more efficient than any other at the time. COMSAT patented and used this technology on all of its space satellites. Lindmeyer did not benefit financially from his invention as he was a salaried employee, and as a consequence he went on to design a new production process that he hoped would cut down the cost of producing photovoltaic cells dramatically, thus making them possible for terrestrial use, but COMSAT was not interested.

In 1973 Lindmeyer and Varadi decided to leave COMSAT to set up their own company to develop terrestrial cells. In February, Solarex was founded. Varadi took on the task of raising funds. In 1972, attempts to obtain funding from venture capitalists were not successful, as they remained wary of photovoltaics and did not trust two scientists to manage a business. But they eventually were able to raise \$250,000 from friends and family. Manufacturing began in August. Within eight months, Solarex became profitable. Vardi later recalled,

"Two months after we launched our company the oil crisis happened, in 1973, at that point we got a lot of publicity from the media, and soon enough, instead of us having to find people, people were coming to us from across the country. Also it was very innovative at the time, we were not selling refrigerators so it triggered people's interest, and people who needed this technology knew where they could get it."

Solarex's fast growth was placed in jeopardy when COMSAT sued it for patent infringement in 1974 but the case was promptly dropped. Solarex sales during the first years were concentrated in niche markets, such as powering watches and calculators. Solarex was the 26 first US company to collaborate with Japanese companies to make solar calculators and produced remote-area power supplies for radio repeaters. However these orders were small and not consistent.

Solarex's big breakthrough came in 1979 when it obtained equity funding from two European companies. Holec, a Dutch electrical company, and Leroy-Somer, a French electric power generating company, invested to obtain Solarex's expertise and license in manufacturing photovoltaic cells in order for them to exploit the European

markets, but the most significant investment for Solarex was a \$7m investment from Amoco. With an apparently booming photovoltaics market due to supportive government policies, Solarex spent \$7m on a new “breeder” plant powered by PV cells to produce PV cells. To show its support, Amoco installed Solarex photovoltaic panels on one of the service stations located at its head office in Chicago.

2.2 CALCULATION OF SUNSHINE DURATION

Solar radiation data provide information on how much of the sun’s energy strikes a surface at a location on the earth during a particular time period. These data are needed for effective research in solar-energy utilization. Due to the cost of and difficulty in solar radiation measurements and these data are not readily available, alternative ways of generating these data are needed. In this paper, a review is made on the solar energy modeling techniques which are classified based on the nature of the modeling technique

Solar energy is the portion of the sun’s energy available at the earth’s surface for useful applications. The measured solar energy values can be used for developing solar energy models which describes the mathematical relations between the solar energy and the meteorological variables such as ambient temperature, humidity and sunshine ratio. These models can be later used to predict the direct and diffuse solar energy using historical metrological data at sites where there is no solar energy measuring device installed

In study of solar energy, information on solar radiation and its factors at a given location is very necessary. Solar radiation data are needed by solar engineers, architects and agriculturists for many applications for example solar heating, cooking, drying and interior illumination of buildings. For this purpose, some mathematical modeling assuming perfect and specula reflectance can be found in the literature

During the first step of calculations the basic spatial geometrical characteristics for each pixel are determined. Then it is checked whether the sunshine can theoretically reach the observed grid plot and whether there is no obstacle between the sun and this surface. The plot can be located on the shaded side of the hill itself, or it can be hidden by the slope, which is in front of the observed surface (shadowing effect of terrain). This algorithm is applied for each grid plot. This calculation is repeated in each time step for the actual sun position (angle and declination), which depends on local time. Output from this subroutine is sunshine duration during the optional time range, e.g. hours, one or several days

2.2.1 CALCULATION OF POTENTIAL ENERGY INCOME

During the next step the potential energy income is calculated for each grid plot. The potential energy income is output from this subroutine. For the plot with general slope β the equation (1) was used as it is described in Kittler and Mikler (1986)

$$^c E_{b\beta} = ^p E_{b\beta} + ^d E_{b\beta} + ^r E_{b\beta} \quad [W m^{-2}] \quad (1)$$

Where $^c E_{b\beta}$ global radiation, $^p E_{b\beta}$ direct radiation, $^d E_{b\beta}$ diffuse radiation, $^r E_{b\beta}$ reflected radiation.

The component of the direct radiation $^p E_{b\beta}$ on grid cell with slope β is calculated according (2), based on direct radiation incidence $^p E_{b\alpha}$ on surface normal to sun beam

$$^p E_{b\beta} = ^p E_{b\alpha} \cos(i) \quad [W m^{-2}] \quad (2)$$

while

$$^p E_{b\alpha} = E_s \frac{\sin(h_s) - 0.17(T_s - 1)}{\sin(h_s) + 0.106T_s} \quad [W m^{-2}] \quad (3)$$

$$\cos i = \cos \beta \cdot \sinh_s + \sin \beta \cdot \cosh_s \cdot \cos(A'_s - A'_\beta) \quad (4)$$

III STORAGE AND APPLICATION OF SOLAR POWER

3.1. PHOTOVOLTAICS

Photovoltaic are solar cells that produce electricity directly from sunlight. The solar cells are made of thin layers of material, usually silicon. The layers, after treatment with special compounds, have either too many or too few electrons. When light strikes a sandwich of the different layers, electrons start flowing and an electric current result . Photovoltaic are used throughout the nation and elsewhere to operate appliances, provide lighting, and to power navigation and communication aids. Photovoltaic panels provide power for equipment in space ships and satellites. PV cells supply power needed to operate many kinds of consumer products such as calculators and watches. Photovoltaic systems provide electricity to remote villages, residences, medical centers, and other isolated sites where the cost of photovoltaic equipment is less than the expense of extending utility power lines or using diesel-generated electricity .

Bhuiyan *et al.*, studied the economics of stand-alone photovoltaic power system to test its feasibility in remote and rural areas of Bangladesh and compared renewable generators with nonrenewable generators by determining their life cycle cost using the method of net present value analysis and showed that life cycle cost of PV energy is lower than the cost of energy from diesel or petrol generators in Bangladesh and thus is economically feasible in remote and rural areas of Bangladesh.

photovoltaic technologies, ranging from silicon to thin films, multi-junction deployment of the existing solar cells, and for each technology identified improvements and innovations needed for further scale-up

3.2 SOLAR THERMAL

Solar Thermal power is heat energy obtained by exposing a collecting device to the rays of the sun. A solar thermal system makes use of the warmth absorbed by the collector to heat water or another working fluid, or to make steam. Hot water is used in homes or commercial buildings and for industrial processes. Steam is used for process heat or for operating a turbine generator to produce electricity or industrial power.

There are several basic kinds of solar thermal power systems including “flat plate” solar water heaters; concentrating collectors, such as central tower receivers; and parabolic trough and dish collectors

3.2.1. FLAT PLATE SOLAR WATER HEATERS

Water flows through tubes that are attached to a black metal absorber plate. The plate is enclosed in an insulated box with a transparent window to let in sunlight. The heated water is transferred to a tank where it is available for home, commercial or institutional use.

3.2.2. CENTRAL TOWER RECEIVERS

In order to produce steam and electricity with solar thermal energy, central receivers have a field of tracking mirrors

called heliostats to focus sunlight onto a single receiver mounted on a tower. Water or other heat transfer fluid in the tower is heated and used directly or converted into steam for electricity.

3.2.3. PARABOLIC DISHES OR TROUGHS

Curved panels which follow the direction of the sun's rays and focus the sunlight onto receivers. A liquid inside the pipes at the receivers' focal point absorbs the thermal energy. The thermal energy received can be converted to electricity at each unit or transported to a central point for conversion to electricity.

3.3. SOLAR STILLS

Solar stills are systems designed to filter or purify water. The number of systems designed to filter water have increased dramatically in recent years. As water supplies have increased in salinity, have been contaminated, or have experienced periods of contamination, people have lost trust in their drinking water supply. Water filtration systems can be as simple as a filter for taste and odor to complex systems to remove impurities and toxins. Solar water distillation is one of the simplest and most effective methods of purifying water. Solar water distillation replicates the way nature purifies water. The sun's energy heats water to the point of evaporation. As the water evaporates, purified water vapor rises, condensing on the glass surface for collection

This process removes impurities such as salts and heavy metals, as well as destroying microbiological organisms. The end result is water cleaner than the purest rainwater. Solar energy is allowed into the collector to heat the water. The water evaporates only to condense on the underside of the glass. When water evaporates, only the water vapor rises, leaving contaminants behind. The gentle slope of the glass directs the condensate to a collection trough, which in turn delivers the water to the collection bottle.

3.4 SOLAR COLLECTOR

A solar collector, the special energy exchanger, converts solar irradiation energy either to the thermal energy of the working fluid in solar thermal applications, or to the electric energy directly in PV (Photovoltaic) applications. Solar collectors are usually classified into two categories according to concentration ratios non-concentrating collectors and concentrating collectors. A non-concentrating collector has the same intercepting area as its absorbing area, whilst a sun-tracking concentrating solar collector usually has concave reflecting surfaces to intercept and focus the solar irradiation to a much smaller receiving area. After the thermal energy is collected by solar collectors, it needs to be efficiently stored when later needed for a release. Thus, it becomes of great importance to design an efficient energy storage system. Section 3 of the present paper focuses on the solar thermal energy storage, discussing its design criteria, desirable materials and emerging technologies for heat transfer enhancement. There are three main aspects that need to be considered in the design of a solar thermal energy storage system:

- Technical properties,
- cost effectiveness
- Environmental impact.

Cost effectiveness determines the payoff period of the investment, and therefore is very important. The cost of a solar thermal energy storage system mainly consists of three parts storage material, heat exchanger and land cost.

This paper has reviewed the state of the art on solar thermal applications, with the focus on the two core subsystems: solar collectors and thermal energy storage subsystems. A variety of solar collectors have been discussed, including non-concentrating types and concentrating types. Among non-concentrating collectors, the PVT solar collectors show the best overall performance. Sun-tracking concentrating solar collectors have also been examined, in terms of optical optimization, heat loss reduction, heat recuperation enhancement, different sun-tracking mechanisms. Three different types of concentrating solar collectors have been described and compared: heliostat field collectors, parabolic dish collectors and parabolic trough collectors. The materials used for high-temperature thermal energy storage systems have been compared, and a comparison between different categories of thermal storage systems has been presented.

Heat transfer enhancement is also essential to overcome the poor heat transfer in these applications. For this purpose, graphite composites and metal foams are found to be the ideal materials. Lastly, the current status of existing solar power stations has been reviewed, with potential future research developments being suggested.

Solar cooking is one possible solution but its acceptance has been limited partially due to some barriers. Solar cooker cannot cook the food in late evening. That drawback can be solved by the storage unit associated with in a solar cooker. So that food can be cook at late evening.

3.5 SOLAR COOLING

Solar cooling consists of using thermal energy collected from the sun as the principal energy input for the cooling system to cool and dehumidify the space. This replaces the existing electrical power input typically required in a vapor compression refrigeration cycle. The benefit of this system is that it has the potential to reduce the amount of electricity used (and carbon dioxide produced from the generation of electricity) during Canada's hot summer months when the demand on the power grid is at its highest. These systems can be effective as the availability of solar radiation coincides with the energy demands imposed on buildings by cooling loads, allowing for the greatest amount of cooling to be generated when it is needed most .

IV CONCLUSION

Solar energy is one of the most promising renewable. It is one of the fastest growing industries worldwide and in order to maintain this growth rate need for new developments with respect to material use and consumption, device design, reliability and production Technologies as well as new concepts to increase the overall efficiency arises.

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