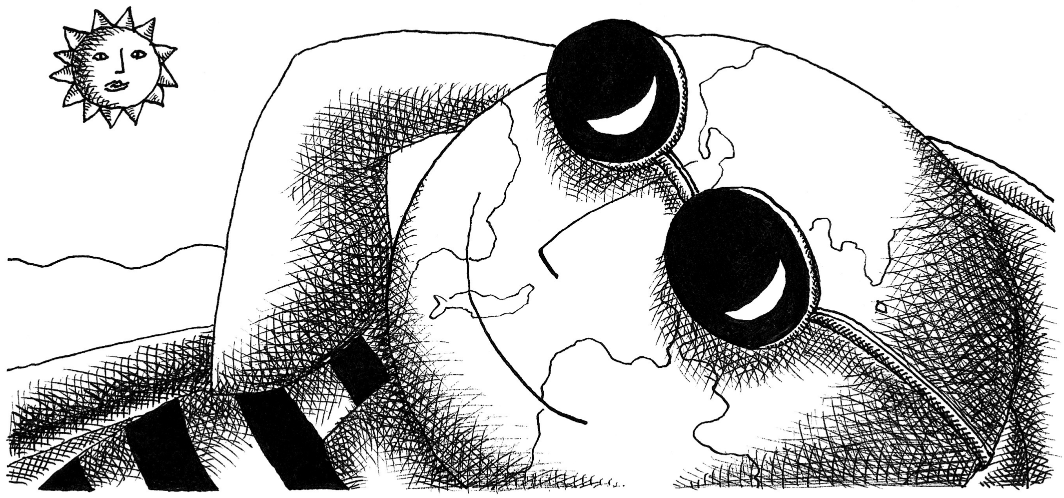


Solar Energy

With an average of over 300 sunny days a year, Israel is an ideal laboratory for testing one particularly promising alternative to fossil fuels: solar energy. In contrast to fossil fuels, the sun provides a clean, cost-free, and virtually inexhaustible source of energy. Every 44 minutes as much energy strikes the earth in the form of solar radiation as is used in a whole year throughout the world. Yet for all its potential, solar energy has barely been exploited. There are three main stumbling blocks: first, since solar radiation arrives in dilute, unfocused form, large areas are required to collect it in significant amounts; second, the sun provides an intermittent source of energy, available only in the daytime and in clear weather; and third, while solar energy can be easily harvested in desert areas, using collectors, it is usually needed in population centers, where empty terrain is scarce. The Weizmann Institute of Science is attacking the problem of solar energy on various fronts, bringing closer the day when humankind can make full use of the gift of sunshine.

Research Facilities

Solar Tower

Solar research on the Weizmann campus takes place at the Canadian Institute for the Energies and Applied Research (CIEAR), a 3,000-kilowatt facility dedicated in 1988. One of the three most sophisticated solar research facilities in the world, the Canadian Institute unites basic research with industrial needs in order to design new methods of exploiting concentrated solar energy.

Major features of the facility include a field of 64 mirrors, or heliostats, each measuring 7 by 8 meters. These mirrors track the movement of the sun and are controlled by a computer that calculates the sun's position relative to the earth every second of the year. The light collected in the field is redirected to a receiving tower at the field's southern edge. This 54-meter tower contains five separate experimental stations; light can be reflected toward any or all of these stations, allowing a number of experiments to be carried out simultaneously.

Solar Furnace

Many Institute solar technologies underwent initial testing at the Rowland and Sylvia Schaefer Solar Research Complex, a 15-kilowatt facility dedicated in 1986. This installation featured a 100-square-meter mirror that reflected sunlight onto a concentrating dish, 7 meters in diameter, which in turn focused the energy onto a spot approximately 10 centimeters in diameter. The Schaefer solar furnace could achieve solar concentrations of up to 7,000 times the intensity of natural sunlight. ●

Toward Commercial Solar Power

One reason industry is slow to embrace solar power plants: burning fossil fuels is still cheaper than harnessing the energy of the sun. Weizmann Institute scientists are developing technologies aimed at making solar power commercially competitive and speeding its transition from lab to life.

The Pilot Plant

Commercial solar power stations can bring enormous ecological benefits. Each square meter of the station's solar field can produce 500 kilowatt hours of electricity annually, drastically lowering the amount of CO_2 emission that results from the burning of fossil fuels. Over 25 years this would result in cumulative savings of 12 tons of CO_2 emission per square meter of solar field, eliminating 100,000 tons of CO_2 emission annually.

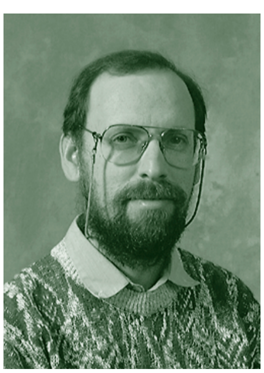
The commercial viability of such solar-powered electricity generation is being examined in a pilot system constructed at CIEAR on the Weizmann campus in collaboration with Rotem Industries Ltd. and Ormat Industries Ltd., both of Israel, and Boeing of the United States. The system's advantages stem from a unique combination of solar collection, concentration, and conversion technologies.

While making use of the Weizmann solar research facility's existing solar tower and heliostat field, the pilot plant also benefits from improved design over previous systems. Rather than being located at the top of a tower, the production facilities – including concentrators, receivers, and turbogenerators – are located at ground level. To make this set-up possible, the Weizmann Institute team designed unique "beam down" optics: a mirror installed on the tower reflects the radiation down to the facilities on the ground. The sole function of the tower will now be to support a reflecting mirror, making construction significantly simpler and cheaper; in addition, the "beam down" optical system can be used for a variety of solar applications.

The installation is designed to operate a gas turbine in a hybrid mode that includes both solar power and conventional fuel. The flexibility to operate on either solar power or gas, or a combination of the two, guarantees a steady supply of electricity even during inclement weather. ●

THE WEIZMANN EXPERIMENTAL FACILITY MAY SERVE AS A BASIS FOR COMMERCIAL POWER STATIONS

Prof. Jacob Karni



Dr. Abraham Kribus

Taking a Lot of Heat

The heart of any solar power system is a receiver – a device that converts solar energy to a more useful energy form such as heat; a heated gas or fluid can then operate a turbine to produce electricity. Systems based on standard solar receivers have been inefficient because they are unable to operate at the high temperature and pressure required by modern power generation equipment.

The Weizmann Institute's first breakthrough in this area was the Directly Irradiated Annular Pressurized Receiver, or DIAPR, a new type of solar receiver developed by **Prof. Jacob Karni, Dr. Abraham Kribus, Rahamim Rubin**, and **Dr. Pinchas Doron** of the Solar Research Facilities Unit, in cooperation with a team headed by Dan Sagie of Rotem Industries Ltd. This device contains a unique radiation absorber nicknamed "porcupine," in reference to the hundreds of ceramic pins that line its inner walls. The pins are arranged in a carefully designed matrix that allows for the maximum absorption of sunlight while preventing cracks that might result from extreme changes in temperature. The "porcupine" uses sunlight to heat pressurized air, which in turn operates a conventional gas turbine to produce electricity.

The DIAPR receiver incorporates another structural advance: the special cone-shaped window that lets in sunlight. This quartz window has a unique geometrical design allowing it to withstand five times the pressure that could be sustained by a similar steel cone. The pins inside the receiver point toward this window – that is, toward the incoming light.

The DIAPR's innovative design allows it to transfer heat much faster and more efficiently than other solar receivers. It can heat air to over 1,300ºC (2,370ºF), hot enough for gas turbine operation and for high-efficiency industrial applications. Two industry-led projects, collaborating with the Weizmann Institute, are currently developing commercial solar power systems that will be using a DIAPR-type receiver.

Meanwhile, Institute researchers have designed a new receiver with an even more impressive performance. Using a new solar energy conversion method they dubbed "control seeding," Ph.D. student Rudi Bertucci and Karni succeeded in heating air to over 1,700ºC (3,100ºF) and inert gas to about 2,000ºC (3,600ºF). In this new receiver, called the Non-Isothermal Directly Irradiated Particulate Enhanced Receiver (NI-DIPER), the gas is "seeded" with tiny carbon particles that absorb sunlight and then transfer the heat to the surrounding gas, increasing the overall efficiency of the system. This research may prove useful in such high-temperature processes as the production of hydrogen by splitting water, magneto-hydrodynamic power generation, and space propulsion, as well as in numerous high-temperature technologies, including future gas turbines and gas dynamic lasers.

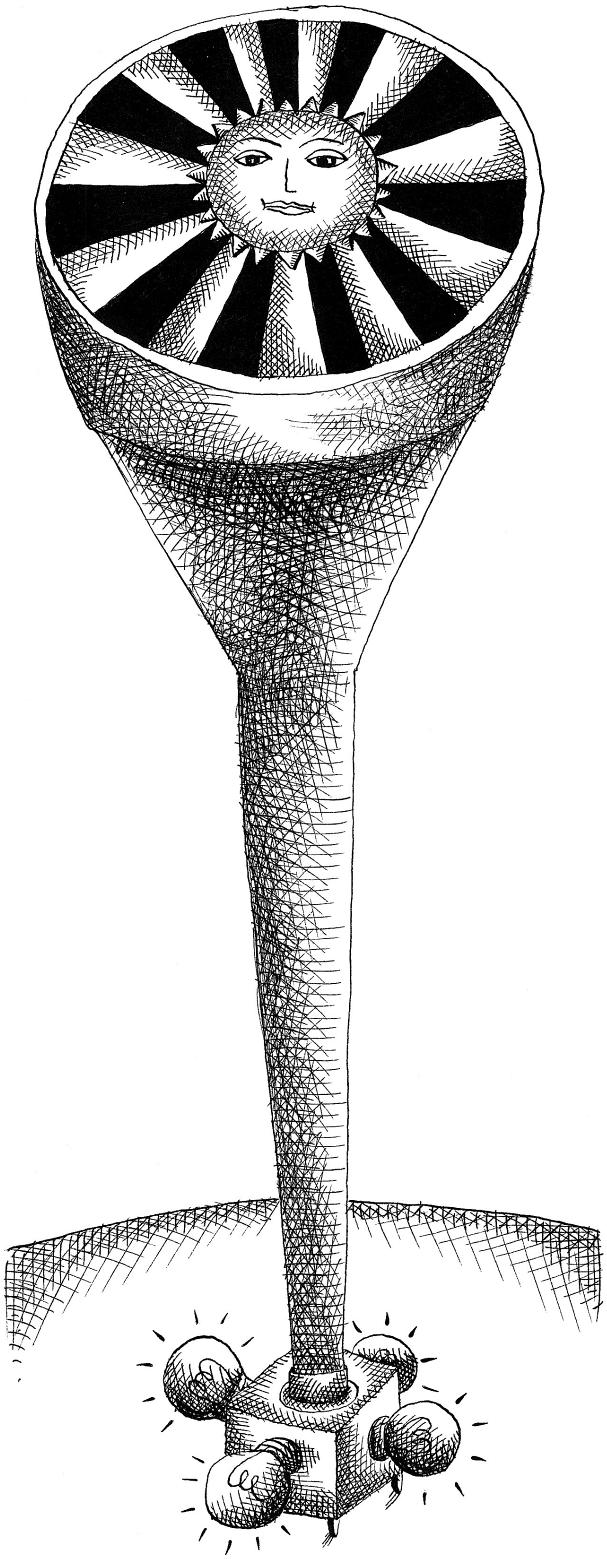
In parallel with the receiver program, Institute researchers have further improved solar energy collection technologies. One challenge was to reduce the loss of energy. The Institute team developed a new strategy: since high temperature increases heat loss, the receiver may be separated into segments of gradually increasing temperature. The high temperature would then be present only in the last segment, all the rest being cooler and hence less prone to losing heat. Test results with an appropriately modified DIAPR show that under certain conditions this strategy can reduce energy loss by a factor of three; in addition, it permits efficient operation of the receiver at moderate concentrations of sunlight. This method is already being implemented in one of the two industry projects mentioned above. ●

Solar Concentrators

Most of today's turbines use steam to produce electricity. Seeking both to improve efficiency and to minimize the ecological damage associated with these systems, electric companies have recently started using gas rather than steam to power turbines. However, state-of-the-art turbines require pressurized air at temperatures exceeding 1,000°C. Heating air to such temperatures with solar energy – rather than the burning of fossil fuels – demands that the concentration of sunlight reaching the Earth be increased by a factor of several thousand.

High concentration on a large scale is best achieved in two stages: first, mirrors collect and focus light onto a small area; then a secondary concentrator, called an optical funnel, further concentrates the light. Weizmann Institute researchers have developed optical "funnels" with a unique geometrical structure that allows them to concentrate sunlight to 10,000 times its normal intensity. The researchers demonstrated that such funnels can be efficient and inexpensive to build, and continue to test various optical devices with a view to achieving even higher concentrations. ●

CONCENTRATORS CAN INTENSIFY SUNLIGHT BY 10,000 TIMES



From Sunlight to Fuel

Institute scientists are exploring a number of ways in which sunlight can make the most of other forms of energy. They are using concentrated solar radiation to increase the productivity of low-grade natural gas, produce synthetic fuel, and extract hydrogen fuel from water or methane.

"Reformed" Gases

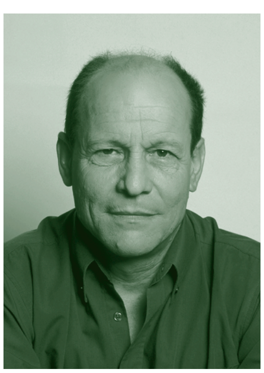
Solar energy and the more traditional fuels are not mutually exclusive. In fact, sunlight may help industry make the most of its conventional energy sources by increasing their energy content.

Weizmann Institute researchers are developing a method for upgrading combustion gases, using solar energy. The goal is to turn low-grade gases – such as methane, a colorless, odorless gas that occurs abundantly in nature – into a stable, energy-rich mixture called synthesis gas, or syngas, which has been commonly used in industry since the beginning of the 20th century – for example, in the production of hydrogen. Syngas, composed mainly of hydrogen and carbon monoxide, offers a substantial increase in energy output. Because its caloric value is approximately 25 percent higher than that of methane, a smaller quantity is needed to produce the same amount of energy. This in turn means that pollution is reduced by one-fourth.

Syngas has numerous uses. It can be burned in a conventional gas turbine to produce electricity, an application developed by Weizmann researchers in collaboration with a German research institute and an Israeli industrial partner in a project called Solar-Assisted Syngas-Driven Power System, or SOLASYS. Syngas can also be used as a synthetic fuel or in fuel cells, or employed as a starting material for a variety of petrochemical products, from ammonia and its fertilizer derivatives to methanol and different types of alcohols, acids, and other chemicals.

SUNLIGHT CAN INCREASE THE EFFICIENCY OF TRADITIONAL FUELS

The solar process for making syngas, called "reforming," is a catalytic reaction, using steam, that takes place in a solar reactor. The Weizmann team, led by **Michael Epstein**, head of the Solar Research Facilities Unit, and **Prof. Jacob Karni**, takes advantage of the knowledge gained in the Institute's earlier projects – the chemical heat pipe (see p. 48) and the DIAPR receiver (see p. 37) – to create a new solar reactor. This research may open new horizons in solar reforming technology by allowing an efficient reaction to take place at temperatures well above 1,000ºC (1,800ºF). ●



Michael Epstein

Biomass Fuel

People have used biomass for cooking and heating for thousands of years. Yet this organic matter – plant materials and urban and animal waste – remains probably the most underused source of renewable energy. In the United States, for example, biomass currently provides 4 percent of energy, while it could easily supply 20 percent. Moreover, in addition to supplying energy, use of biomass can solve the mounting problem of garbage disposal; millions of tons of agricultural waste, a large proportion of municipal waste, and mountains of sawdust all constitute biomass waiting to be turned into clean energy.

The simplest and most common way of deriving energy from biomass is by burning it, but this approach is limited both in efficiency and in the range of its applications. A newer method is biomass gasification, a process that turns organic matter into energy-rich gas. At the Weizmann Institute, **Michael Epstein** heads a project in which biomass is gasified using solar energy. The researchers are developing a solar reactor for the optimal conversion of dispersed biomass particles into synthesis gas. They are using cellulose as sample plant material, but the approach is applicable to all types of biomass. ●

BIOMASS GASIFICATION COULD SAVE PRECIOUS SPACE IN WASTE LANDFILLS

Early Achievements

Self-healing sounds like a property of living tissue, but **Prof. David Cahen** and his colleagues have discovered that the phenomenon also exists in a semiconductor used to manufacture thin-film solar cells. Their research, conducted in part at the European Synchrotron Research Facility in Grenoble, has revealed that in copper indium diselenide – one of the strongest candidates for replacing silicon in photovoltaics – certain chemical bonds break easily, leaving the "freed" copper atoms to wander until they reach damaged areas, which they then repair. Understanding this phenomenon, which is driven by the material's tendency to try to remain in equilibrium, has bolstered confidence in this type of cell and paved the way for manufacturing longer-lasting solar cells that can withstand harsh conditions.

In the late 1980s, seeking to establish why some solar cells tend to crack, **Prof. David Cahen** discovered that the expensive hard glass commonly used in photovoltaic cells is fundamentally unsuited to the job: when expanding or shrinking, it behaves differently than do the materials used to manufacture the cells' upper layers. No such compatibility problem is observed with the cheaper, regular glass. Further research by other scientists revealed that because it contains sodium, regular glass ensures solar cell durability, but why it does so was not clear. In 1999, Cahen showed that sodium serves as a catalyst for oxidation, a process that improves the cells' sturdiness and efficiency. These findings have led to a highly efficient and reproducible method for manufacturing durable thin-film solar cells.

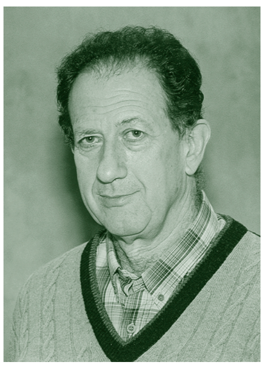
Solar Hydrogen

Hydrogen is the most plentiful element in the world. It is also a pollution-free fuel that has been used successfully in experimental automobiles. Why don't we make greater use of hydrogen as an energy source? Unfortunately, the most common method of hydrogen production at present is highly polluting: in this process, called steam reforming, methane interacts with steam; as a byproduct of this reaction, large amounts of carbon dioxide are dumped into the atmosphere. Every year some 20 million tons of hydrogen are produced by reforming for industrial use, mainly for the manufacture of fertilizers, methanol, and other chemicals. But if an efficient, pollution-free method for its production were developed, hydrogen could become the fuel of the future, replacing coal, oil, and natural gas.

A "clean" solar approach for extracting hydrogen from water is being explored by **Michael Epstein**. He is using concentrated sunlight to extract metals from their oxides. Metals extracted using this technique can then be induced to react with water, releasing hydrogen. An example is solid zinc oxide, which reacts with carbon when heated to temperatures of 1,200-1,300ºC. The gaseous zinc is released, then condensed and stored; when reacted with water, it yields zinc oxide and hydrogen. In addition to the hydrogen thus made available for use as fuel, the elemental zinc can be used in zinc/air batteries – a very efficient converter of chemical to electrical energy. Epstein, working with **Prof. Amnon Yogev**, spent four years developing a laboratory prototype. A new project, in collaboration with researchers from several European countries, aims at upscaling the process for industrial use, with the help of the Institute's unique beam-down optics.

Meanwhile, **Prof. Abraham Kogan,** working at the Solar Research Facilities Unit, is developing a "clean" solar method for extracting hydrogen from methane: the gas is split into carbon and hydrogen atoms with the help of solar heat. The only byproduct of this reaction is so-called carbon black – pure carbon in powder form. Not only is carbon black free of the environmental hazards associated with carbon dioxide, but its production makes Kogan's approach economically attractive: the chemical industry makes use of carbon black to increase the durability of rubber; in fact, all vehicle tires contain some 10 percent of carbon black.

A MINI-TORNADO KEEPS THE WINDOW CLEAN IN A HYDROGEN-PRODUCING SOLAR REACTOR



Prof. Amnon Yogev, now retired, held the Stephen and Mary Meadow Professorial Chair of Laser Photochemistry

Prof. Abraham Kogan

Abraham Kogan, together with visiting scientist Meir Kogan, has already built a laboratory-scale solar reactor for splitting methane. A major engineering problem had to be solved: in the reactor, the methane is "seeded" with carbon to render it opaque so that the gas will trap solar heat – a transparent gas would simply let the sunlight through without it being heated. However, the seeding, as well as the carbon black produced in the reaction, quickly blackens the reactor's quartz window, preventing it from letting in sunlight. To overcome this obstacle, the scientists developed a system in which two streams of gas pumped into the reactor interact to create a swirling flow pattern similar to the one observed in a tornado. The mini-tornado blows particles away from the reactor window, producing a gas "curtain" that keeps the window clean, while the hydrogen and the carbon black are separated and stored in their designated reservoirs. This ingenious system may find applications in solar reactors where a transparent window must be kept free of floating particles. ●

Developing Better Solar Cells

Solar cells produce electricity just by lying in the sun; they use the energy of photons, the particles of sunlight, to directly generate an electric current, hence their scientific name, photovoltaics. Although photovoltaic technology is still considered too expensive for large-scale applications, it increasingly finds its way into "niche" markets in locations with no readily available connection to the electricity grid – such as satellites, boats, camps, or remote settlements. According to PV News, *between 1995 and 2000 the world market for photovoltaics more than tripled, from 78 to 288 megawatts per year; and by 2020 it is expected to increase more than tenfold, to 4 gigawatts per year. Weizmann Institute scientists are exploring new methods and materials for making photovoltaics a viable energy source in small- and large-scale applications.*

Collection Techniques

Natural sunlight is a dilute energy source: to produce a large amount of electricity, solar cells must be spread out over a very wide area. If today's expensive photovoltaic units were replaced by optical concentrators that intensified sunlight by, say, a factor of 500, then the cell needed to produce the same amount of electricity would be 500 times smaller. The savings in silicon alone would go a long way toward making solar-produced energy economically attractive.

Focusing highly concentrated sunlight onto small solar cells, **Prof. Amnon Yogev** found that when filters are used to split sunlight into a number of spectral ranges, heating is reduced and efficiency of the photovoltaic unit is doubled. If the unused wavelengths are exploited for other uses, such as providing the energy for the "absorption cooling" that powers some refrigeration and air conditioning systems, the savings can be even greater.

Economic factors such as these hold the key to bringing solar energy to vast areas of the world that have no existing infrastructure for power generation and transmission based on fossil fuels. The investment necessary is modest: a 10-kilowatt photovoltaic unit could support the electric lighting, refrigeration, and communications infrastructure of an entire village. Anticipating the difficulties of maintaining solar installations in isolated areas, Institute scientists envisage building photovoltaic units complete with satellite communications networks, to allow maintenance reports to be transmitted automatically. ●

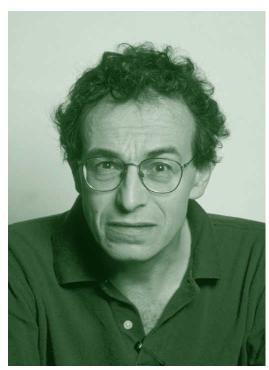
A 10-KILOWATT PHOTOVOLTAIC UNIT COULD SUPPLY ELECTRICITY TO AN ENTIRE VILLAGE

New Materials

Today most commercial solar cells are still made of silicon, which is stable but relatively expensive; however, several other materials are being developed for future use in photovoltaics. The goal: to produce solar cells that are both cheap and durable. The front-runners are thin-film technologies, in which a thin layer of a fine-grained photoelectronic material is deposited on an inexpensive large-area surface such as window glass.

Weizmann Institute research may speed up the application of one of the most advanced thin-film materials in solar cells. Cadmium telluride-based photovoltaics are already in the pilot stage of development and may soon be manufactured commercially on a large scale in the United States and Europe; but these cells tend to deteriorate over time. Because Institute scientists had in the past managed to solve major theoretical and practical problems related to photovoltaics, the U.S. Department of Energy asked them to address the deterioration of cadmium telluride-based units. The Institute team, headed by **Profs. David Cahen** and **Gary Hodes** of the Materials and Interfaces Department, revealed how these solar cells can be rendered more stable. Using chemical and physical investigation methods, the scientists showed, for example, that the cells must be used in a dry, preferably oxygen-free environment. The researchers are conducting further studies aimed at enhancing the stability of cadmium telluride cells and understanding the basic science underlying their performance. Such an understanding may help not only to develop better cells but also to overcome the psychological barriers – particularly, concerns over reliability – impeding the acceptance of experimental solar energy technologies.

In another project, Profs. Cahen and Hodes are investigating the mechanism of action of an innovative type of solar cell invented in the early 1990s in Switzerland. The dye-sensitized solar cell, or DSSC, is made of an organic material that is incorporated into a porous thin film consisting of microscopic semiconductor particles held together like beads on a string. DSSC cells are radically different from other solar cells in several respects, and until recently it was unclear how exactly they generated electric power. Cahen and Hodes, in collaboration with colleagues in Israel and abroad, have suggested a mechanism that may account for the formation of photovoltage in these cells: apparently, the dye functions much like chlorophyll, the natural photosynthetic pigment in plants. The Institute researchers are currently striving to understand the mechanisms involved in the movement of electrons through DSSC cells. ●



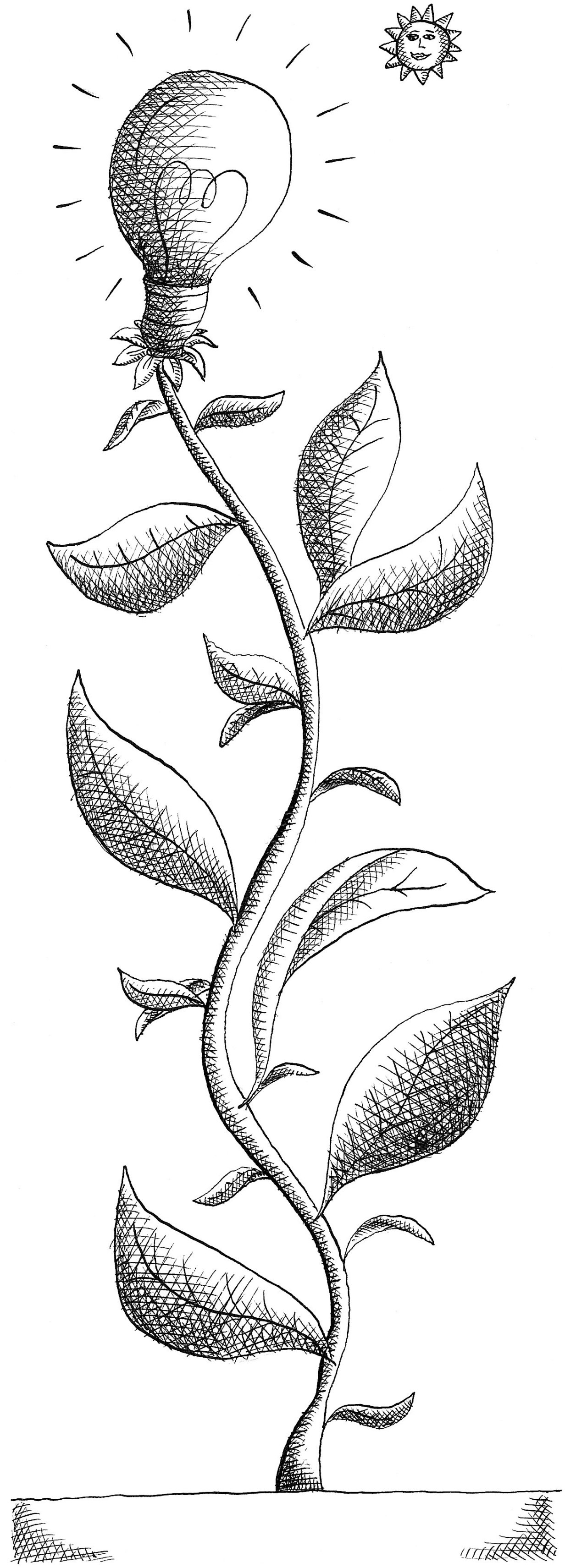
Prof. David Cahen holds the Rowland Schaefer Professorial Chair in Energy Research

Prof. Gary Hodes

Improving the Surface

The efficiency of silicon solar cells is limited by two major problems: surface recombination – the tendency of electrons to become trapped in the surface of the semiconductor; and light reflection from the surface of the solar cells, which can decrease the energy available for electricity production by 10-20 percent.

Prof. David Cahen and his colleagues are improving solar cell performance by eliminating the surface defects common to fine-grained semiconductor materials. This research involves analyzing the defects caused by minute amounts of impurities in the semiconductor, then controlling those defects on the molecular level. Together with **Prof. Avi Shanzer** of the Organic Chemistry Department, Cahen has succeeded in improving semiconductor performance by grafting desirable properties onto organic molecules. Prof. Shanzer is adapting models of chlorophyll, the substance that controls photosynthesis in plants, to improve the semiconductors used in photovoltaic cells. The technique involves dipping the semiconductor into a specially prepared solution containing porphyrins – the “backbone” of chlorophyll molecules. The porphyrin binds to the semiconductor surface, causing the semiconductor to absorb light more efficiently. This in turn induces a greater electric charge in the semiconductor. Developing his approach further, Shanzer’s group is working on synthesizing organic “wires” that would link light-harvesting groups such as porphyrins to a metal ion, creating molecular “antennae” to guide photons to the semiconductor surface. (For more on photosynthesis and solar energy, see p. 49.) ●



Early Achievements

■ **Prof. Reshef Tenne** of the Materials and Interfaces Department and his Ph.D. student Palle von Huth have come up with a new, inverted solar cell design. They have placed an n-type semiconductor in the back (to serve as an absorber) and a p-type material in the front (to serve as a "window"). Their p-type material is a transparent diamond film, an excellent conductor of heat and of electric current, used in several areas of industry but never before applied in photovoltaics. The "inverted" cells offer new ways of studying the properties of photovoltaics. Moreover, if diamond films are replaced by less expensive materials, the new concept may in the future serve to manufacture solar cells for practical applications. Initial testing has revealed that "inverted" cells efficiently produce electric current and that they offer certain advantages – including greater stability and ease of manufacture – over the conventional design.

■ In collaboration with French researchers, **Prof. Tenne** has developed a photoetching technique to improve the efficiency of the silicon used in photovoltaics. The silicon is immersed in an electrolyte solution through which electric current is passed, making the silicon less reflective. As a result, less light energy is lost.

■ **Prof. Tenne** has also created a method for removing chemical impurities from semiconductor materials. He uses infrared laser light to ionize impurity atoms, causing them to move rapidly through the semiconductor. The impurities can then be removed by electrochemical techniques.

The Sun's Many Faces

The ways in which solar energy can be used are nearly as endless as sunshine itself. The variety of solar applications at the Weizmann Institute is a case in point: projects range from harnessing sunlight for space communications and for providing meteorological information, to controlling light-induced chemical reactions and developing a photodynamic therapy for treating cancer.

The Crystal Connection: Solar Lasers in Space

Solar lasers are potentially powerful tools with a variety of applications. Like all photon beams, these lasers can be tuned to various wavelengths, making them useful for photochemical reactions, in which chemical energy is released by exposing reactants to specific colors of the solar spectrum. In another application, high-intensity laser light can be used to destroy organic contaminants in water. Solar lasers may also be used in places where conventional electricity grids are difficult to erect and maintain, as in space. When installed on satellites, they may be employed for communications, for providing meteorological information, for measuring atmospheric pollution, or even for transmitting power between satellites.

At the Weizmann Institute, **Prof. Amnon Yogev** and his colleagues have developed the world's most advanced solar laser: high-intensity solar radiation is absorbed by special crystals, which re-emit the light directly as a photon beam.

Conventional laser production is only 1 percent efficient; and when a fossil fuel such as coal is used to produce the electricity that powers a laser beam, 99 percent of the energy is lost in the process. In Yogev's system, no energy is wasted in the intermediate production of electricity. The result is a laser that utilizes solar energy at 10 percent efficiency, a tenfold increase over conventional methods. This efficiency factor can be raised even further by splitting the spectrum of the highly concentrated sunlight that hits the crystals. When the crystals are exposed to only those spectral bands that are useful for the production of laser light, efficiency reaches 30 percent.

In laboratory conditions, Yogev and his team have produced solar lasers that provide 500 watts of tunable energy, making them applicable to a number of industrial uses. Small-scale demonstrations using solar-pumped lasers for power beaming and communications have been performed at the Weizmann Institute's solar research facilities. ●

SOLAR LASERS CAN BE USED FOR SATELLITE COMMUNICATIONS, FOR PROVIDING METEOROLOGICAL INFORMATION, AND FOR MEASURING ATMOSPHERIC POLLUTION

■ **Prof. Reshef Tenne's** research may reduce surface recombination in solar cells. Working initially with departmental colleague **Prof. Gary Hodes**, Tenne designed a solar cell based on molybdenum disulfide and tungsten diselenide. These layered materials, which are more stable and far less expensive than crystalline silicon, can be transformed into a film by being heated in a gas containing sulfur or selenium. However, the layered compounds, while in some ways ideal for photovoltaic applications, suffer from the surface recombination phenomenon. To overcome this problem, Tenne synthesized a new form of tungsten diselenide and molybdenum disulfide. The synthesized compounds, which fall into the category of inorganic fullerene-like structures and inorganic nanotubes, provide for a superior solar cell surface because they are spherical and virtually seamless.

The Chemical Heat Pipe

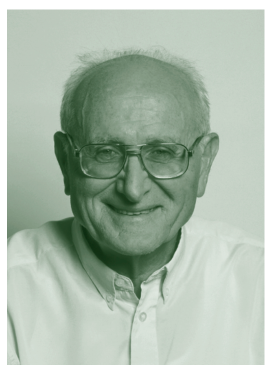
Heat needed to drive various industrial processes accounts for about a third of all the energy consumed by humankind. Currently, generating such heat is a highly polluting affair; it requires either burning fossil fuels or using electricity, which in turn is often derived from polluting energy sources.

The Weizmann Institute's solar technology known as the chemical heat pipe offers a clean and direct method for generating heat using solar energy and storing this heat for future use. Initiated by **Institute Professor Israel Dostrovsky** and **Prof. Emeritus Moshe Levy** at the Schaefer solar furnace, the method was further developed and scaled up under the direction of **Michael Epstein** at Weizmann's Canadian Institute for the Energies and Applied Research. The current installation can absorb about 500 kilowatts of power, a level that brings chemical heat pipe technology closer to the day it can be used in industry.

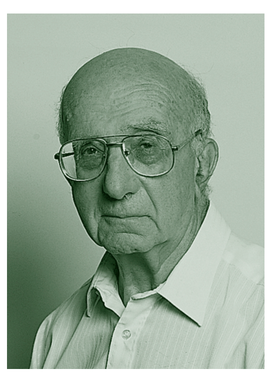
In the chemical heat pipe approach, concentrated solar radiation is used to generate temperatures ranging from 800 to 900ºC. The heat triggers a reversible process in which methane reacts with steam or carbon dioxide to produce synthesis gas. This gas is a portable source of energy: once cooled, it can be stored at high pressure and transported to the point of use. When the gas is exposed to the right catalyst, the reaction is reversed, releasing a large amount of heat at temperatures of up to 700ºC – more than enough for use in most industrial processes and for generating steam, electric power, or both. The Weizmann installation consists of two main elements: a solar reformer on the roof of the solar tower, where methane is converted into synthesis gas, and the William Davidson Methanator at ground level, where synthesis gas is converted back to methane and carbon dioxide.

In addition to providing a solution to the problems of storing and transporting solar-generated energy, chemical heat pipe technology is good for the environment. Because the reaction is reversible, the products released at the user end can be sent back, via another pipe, for reprocessing. In this "closed-loop" system, no gases are released into the air, a distinct advantage over conventional energy sources based on the burning of fossil fuels. ●

THE "CLOSED-LOOP" SYSTEM OFFERS A SOLUTION TO THE STORAGE OF SOLAR ENERGY



Prof. Moshe Levy



Prof. Israel Dostrovsky holds the Agnes Spencer Professorial Chair of Physical Chemistry

From Photosynthesis to Light Therapy

In harnessing sunlight, as in everything else, it pays to see how the experts do it. Hence the rationale to study photosynthesis – the process by which plants expertly convert light into energy.

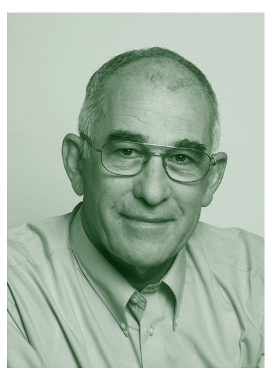
Prof. Avigdor Scherz of the Plant Sciences Department explores the process by which plants capture sunlight and convert it into useful energy. A fundamental exploration of this sort, originally aimed at understanding nature, can lead into unexpected directions, as has indeed happened with Scherz's studies. His research has already been applied to photodynamic therapy, an experimental treatment for cancer, and may lead to further applications in other areas.

Photodynamic therapy, recently approved in the United States for the treatment of advanced esophageal, bladder and lung cancers and for age-related macular degeneration, involves injecting a patient with special light-sensitive drugs, or photosensitizers. These drugs are harmless, but they become toxic when exposed to light. However, photosensitizers presently in clinical use have several serious drawbacks that limit their utilization in photodynamic therapy. Together with **Prof. Yoram Salomon** of the Biological Regulation Department, Scherz has developed a "green" photosensitizer, one based on chlorophyll, the same pigment that make green plants and photosynthetic bacteria such effective light collectors. The "green" drug offers crucial advantages over previously used photosensitizers, including an improved ability to penetrate bulky tumors and a faster clearance from the patient's body. The Weizmann technique involves administering the pigment molecules into the blood and then using fiberoptic surgical techniques to locally illuminate the tumor; the blood vessels feeding the tumor are destroyed within minutes, and as a result – following a single treatment – the tumor tissue dies and disappears. Scherz and Salomon's method is presently tested in clinical trials of prostate cancer at two medical centers in Canada, and more trials with this type of cancer are expected to begin in Israel. Applications for the treatment of other types of cancer are in the pipeline.

Another area where photosynthesis research may find practical application is in the field of biomolecular machines. Scherz's studies of chlorophyll derived from plants and bacteria may lead to the development of new bioelectronic and photoelectronic devices. ●

A PLANT-DERIVED MECHANISM IS LEADING TO AN INNOVATIVE CANCER THERAPY, IN WHICH A SPECIAL LIGHT-SENSITIVE DRUG SELECTIVELY KILLS THE TUMOR

Prof. Avigdor Scherz holds the Yadelle and Robert N. Sklare Professorial Chair in Biochemistry



Prof. Yoram Salomon holds the Charles W. and Tillie K. Lubin Professorial Chair of Hormone Research