TEL AVIV UNIVERSITY
RENEWABLE ENERGY

The search for new, renewable sources of energy is our critical challenge. Tel Aviv University scientists are hard at work developing sustainable technologies that can change our lives in the foreseeable future.

The Center for Renewable Energy gives further momentum to the extensive research already taking place across the campus in this vital field.

POWER SWITCH

Power Switch

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Green Momentum

The Center for Renewable Energy at Tel Aviv University was established to give further momentum to the extensive research into sustainable energy already taking place across the campus. The search for efficient, renewable sources to replace expendable fossil fuels is a critical challenge facing humankind today.

Prof. Yossi Rosenwaks: "Sustainable energy is of existential and strategic importance."

"The world today urgently needs sources of green energy to halt the pollution and ongoing destruction of the planet," says Prof. Rosenwaks, Head of the Center for Renewable Energy. "In Israel, sustainable energy is of existential and strategic importance of the first order. Advanced technology enabling energy production from clean sources will grant energy independence, freeing us from political and economic dependence on the oil and gas of our neighbors—in times of peace, and especially in times of conflict."

The main source of renewable energy in our hot country of blue skies is the sun. If 8% of the area of the Negev was outfitted with photovoltaic systems—converting the sun's rays into electricity—we could supply all the electricity needs of the State of Israel! Yet technological obstacles, such as the need for storing the sun's energy for use at night and on overcast days, as well as for sweeping changes to the national electricity grid, must be overcome.

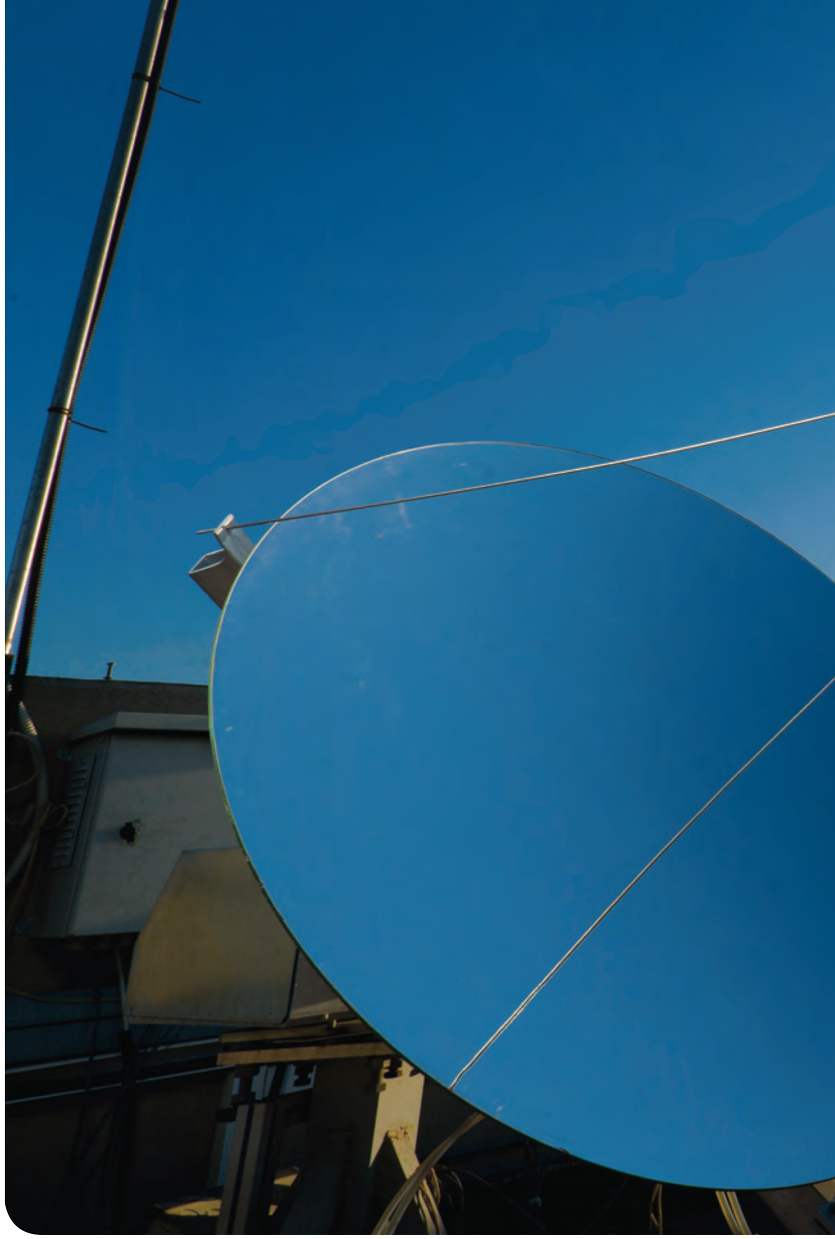
Tel Aviv University researchers have stepped up to this national scientific task: 55 sustainable energy research groups with over 300 scientists in seven faculties—exact sciences, engineering, life sciences, management, law, social sciences, and humanities—and in the Porter School of Environmental Studies are conducting groundbreaking research. They study aspects such as energy storage in fuel cells and batteries; solar-thermal energy; wind turbines; generating electricity through photosynthesis; developing a smart, integrated national electricity grid; nano-antennas; and seaweed biofuel production. (Descriptions of studies follow.) In the past five years alone, this research has produced 100s of patents and about 1000 publications in international journals. The innovative technologies developed in TAU laboratories have enormous economic potential: in an expanding global market of renewable energy, their value could reach billions of dollars.

The Center for Renewable Energy offers researchers from across the campus a shared roof, fostering interdisciplinary collaboration between colleagues from different departments and faculties. The Center holds scientific conferences, provides support for studies, and attracts outstanding research students. It is setting up advanced laboratories in energy storage, solar energy, and biomass energy, and is establishing a national research center on the electric car, together with Bar Ilan University. The Center conducts outreach to increase public awareness of sustainable energy and share University breakthroughs that can change our lives in the foreseeable future.

Prof. Yossi Rosenwaks is head of the Center for Renewable Energy, and head of the Faculty of Engineering's Department of Physical Electronics. He is an international expert in nanometric characterization of semiconductors and photovoltaic solar cells, and leads a research group of 10 scientists. To date, Prof. Rosenwaks has mentored 45 postgraduate students, edited a number of books, and published 120 articles in international journals. He has served as president of the Israel Vacuum Society (2003–2006), and as head of the Wolfson Applied Materials Research Center and the Gordon Center for Energy Studies (2005–2008).

"Solar energy is found in abundance, but it will only become a useful and economically feasible resource if we can improve the efficiency of its conversion to electricity," explains Prof. Kribus, who has been developing solar power plant components for 20 years. "The efficiency of converting energy stored in fuels used in traditional power plants is 40–60%, while solar power plants today produce electricity with an efficiency of less than 20%. This is the main reason why only a few solar power plants have been built around the world."

Currently all thermal power plants—whether fossil fuel- or solar energy-based—work in a similar way. Energy is invested in heating steam or air to 100s of degrees Celsius. The heated steam or air expands and turns the blades of a turbine, which rotates a generator, converting mechanical energy into electrical energy. The indicator of energy usage in the process—*conversion efficiency*—is the ratio of the quantity of energy invested at the source to the amount of energy converted to electricity. Conversion efficiency increases when steam or air is heated to a higher temperature. The challenge facing developers of solar power plants is to achieve the high temperatures produced by burning coal, oil, and gas. This is already possible today using a new technology: the *solar tower*.



Prof. Abraham Kribus is hard at work improving solar tower technology.

Aora Solar's solar tower in Almeria, Spain.
Source: AORA SOLAR.

Here Comes the Sun

Will we, one day, produce electricity from solar energy on a national scale, efficiently, and at a lower cost than at power plants today? Prof. Abraham Kribus, Faculty of Engineering, is developing technologies to convert light into electricity, and the dream...into reality.

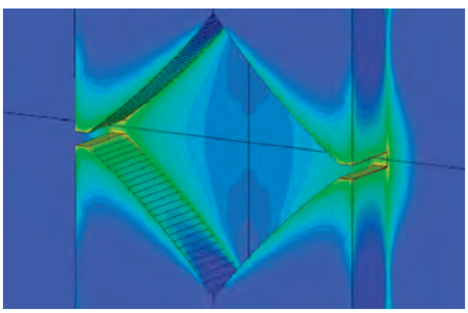
Solar Tower Technology

Solar tower technology uses mirrors to concentrate the sun's rays on a focal point at the top of a tower. Its efficiency could equal that of fossil fuel-based power plants, and is greater than that of solar power plants constructed to date. Prof. Kribus's team is improving solar tower technology by refining the structure and efficiency of the component on which radiation is focused. Optimal design of the component—which absorbs the sun's rays and heats air—will minimize energy loss and enable reaching required temperatures. Researchers employ computerized models to assess designs and materials, testing specific designs in the lab. Heating tower air to a temperature exceeding 1000°C is likely to produce electricity from sunlight with a conversion efficiency of 30%. Other developments by Prof. Kribus and his team include efficient night utilization of solar heat, and a solar technology that breaks down organic waste to generate electricity and fuels such as hydrogen gas, with about 50% efficiency.

Prof. Abraham Kribus, Faculty of Engineering, has been developing solar power plant components for over 20 years. He has a number of patents and developments, which are awaiting application by industry. In the future, his lifework will likely serve as a basis for constructing large power plants operated by renewable energy from the sun.

Prof. Amir Boag: "Our advantage is the successful combination of nanotechnology, optics, and antenna design."

"The most common solar cells are silicon photovoltaic cells, which utilize only 10% of solar radiation to generate electricity. Other types of cells utilize up to 40% of solar radiation, but they are far more expensive," explains Professor Boag. "Our goal is to create a nanometric antenna of minute proportions, capable of absorbing a wide range of frequencies, e.g. infrared, in addition to visible light. In principle, this will utilize up to 85% of the sun's radiation—more than double what the most advanced photovoltaics are capable of today! An array of nano-antennas, each measuring half a micron in size, will collect and tap radiation from a large surface area." Antenna models are based on structures made of gold, aluminum, titanium, or other metals, and manufactured by electron-beam lithography. This method is highly accurate, yet expensive, and will be replaced by a method similar to printing.

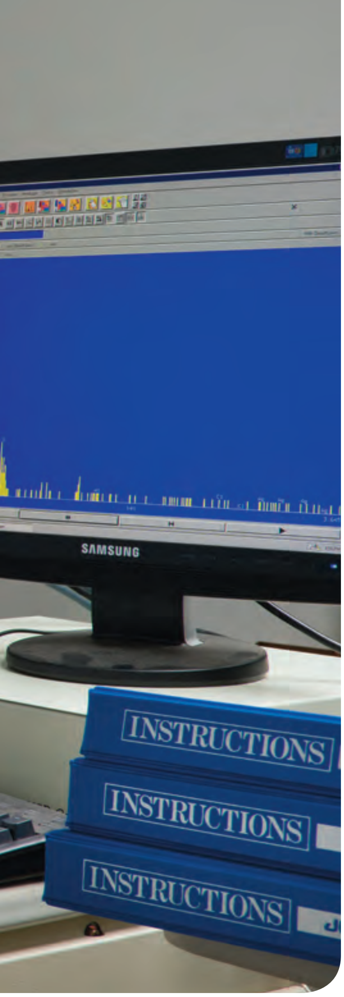


Electric field distribution in the nano-antenna.

Nano-Antennas & Carbon Nano-tubes

Solar energy absorbed by nano-antennas is first converted to alternating current, and then to direct current that can be conveyed to destinations on the power grid. Researchers are developing innovative carbon nano-tube rectifiers made of molecular tube-shaped carbon structures, combining excellent conductivity and hardness. Nano-tubes are connected on one end to a gold contact, creating a conductive contact, and on the other to a titanium contact, creating the rectifier controlling current direction.

Researchers are working toward accurately centering nano-tubes on a newly patented nano-antenna, the *double Vivaldi*, which has two chief advantages: (1) it is broadband, i.e., it absorbs infrared *and* visible light; (2) it can be connected serially in large arrays so that the minute



NANO-ANTENNAS

IT'S A SMALL WORLD

Solar energy is perhaps the most promising source of renewable and clean energy—energy that is available anywhere, any day, and will never run out. However, current technologies for converting solar energy into electricity only make use of a small percentage of sunlight reaching the earth. Professors Amir Boag, Yael Hanein, and Kobi Scheuer from the School of Electrical Engineering are developing a system to increase solar energy utilization using nano-antennas—tiny nanometric-scale antennas.

voltages created on each antenna add up to a high total voltage. The team seeks to further increase rectification of generated voltage by decreasing nano-gaps through which the current travels.

"Our team's advantage is the successful combination of nanotechnology, optics, and antenna design—combining engineering *and* physics," says Prof. Boag. "Interdisciplinary collaboration enables us to discover scientific principles, prove them, and suggest wide applications. We are not content with creating a single model to demonstrate a physical phenomenon, as is customary in fundamental science. We streamline our models and direct lab findings toward practical technological applications." This is why, in addition to their role in solar energy, nano-antennas will have other fascinating applications in night-vision, imaging, and biotechnological diagnostic systems. And because nano-antenna properties change in the presence of a single foreign molecule, they could potentially be used to detect foreign substances.

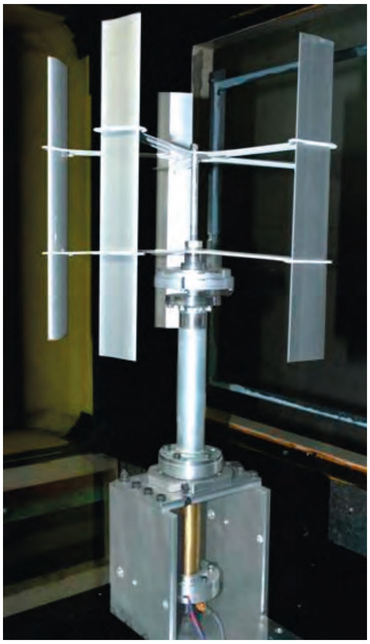
Nano-antenna array as produced in the Tel Aviv University Center for Nanoscience and Nanotechnology.

Professor Amir Boag is on the faculty of the Department of Physical Electronics at the School of Electrical Engineering. Professor Boag's research group numbers over 10 advanced degree students, pursuing research in several areas, including numerical analysis of electromagnetic and acoustic waves, antenna and optical component design, Kelvin probe force microscopy, and radar imaging. Professor Boag has published over 80 scientific papers, presented more than 150 lectures at international conferences, and filed 10 patents. In 2008, he was named Fellow of the IEEE for his contributions to integral equation-based analysis, design, and imaging techniques.

Run Like the Wind

Wind is one of the cleanest forms of energy bestowed upon us by nature, and scientists throughout the world are looking for efficient ways to harness its power. The main hurdle is that wind, its strength, and direction are random, and cannot be accurately predicted or controlled. In Prof. Avi Seifert's laboratory at the School of Mechanical Engineering, innovative technologies to effectively exploit wind energy are being developed.

"Wind as an energy source has great potential in Israel, mainly in elevated areas," says Prof. Seifert. "But before setting up wind turbines across the country we must solve a few technological challenges. First, wind turbines today are only efficient within a certain range of wind speed. When the wind is weaker, turbines cannot be relied upon. Second, wind turbines are noisy, limiting deployment in or near residential areas. Third, they are very large, requiring a lot of space. My research, together with Professors Touvia Miloh and Avi Kribus of the School of Mechanical Engineering, aims to develop small, quiet wind turbines that will operate efficiently at much lower wind speeds. This technology will boost our ability to harness wind power for our needs."

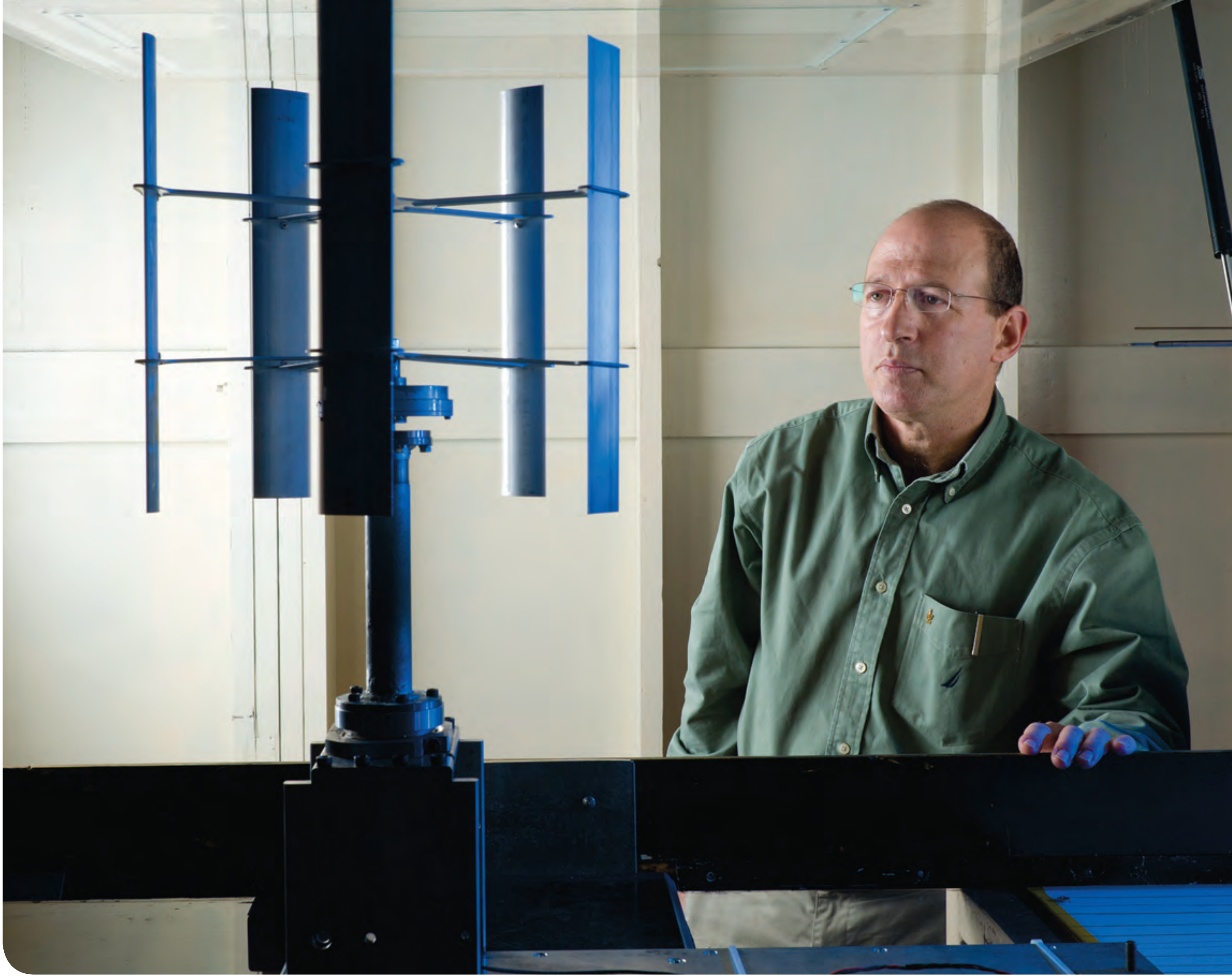


A small vertical wind turbine is tested in the wind tunnel of the School of Mechanical Engineering at Tel Aviv University's Faculty of Engineering.

Harnessing the Wind

Professor Seifert's research team at the TAU Meadow Aerodynamics Laboratory is at the international forefront of *active flow control*. The team, at work for two decades, has developed a system that increases turbine energy yield by using a combination of wind-flow sensors and current activators—minute devices that create controlled turbulence near turbine blades in response to information from detectors. In this fashion, with a small investment of energy at the right place and time, it is possible to decrease the randomness of wind activity, thereby increasing overall wind turbine performance and output. In the future, this novel system will allow installation of efficient wind turbines at sites that today are considered uneconomical—locations with low or changeable wind speeds, or with unstable wind direction, as well as in urban and populated areas.

When this vision is realized, we will be able to harness wind directly to generate electricity and store energy, charge batteries, pump water, and more. Using clean wind energy rather than polluting fuels will contribute to our health and that of the environment. Yet according to Prof. Seifert, today wind energy operations



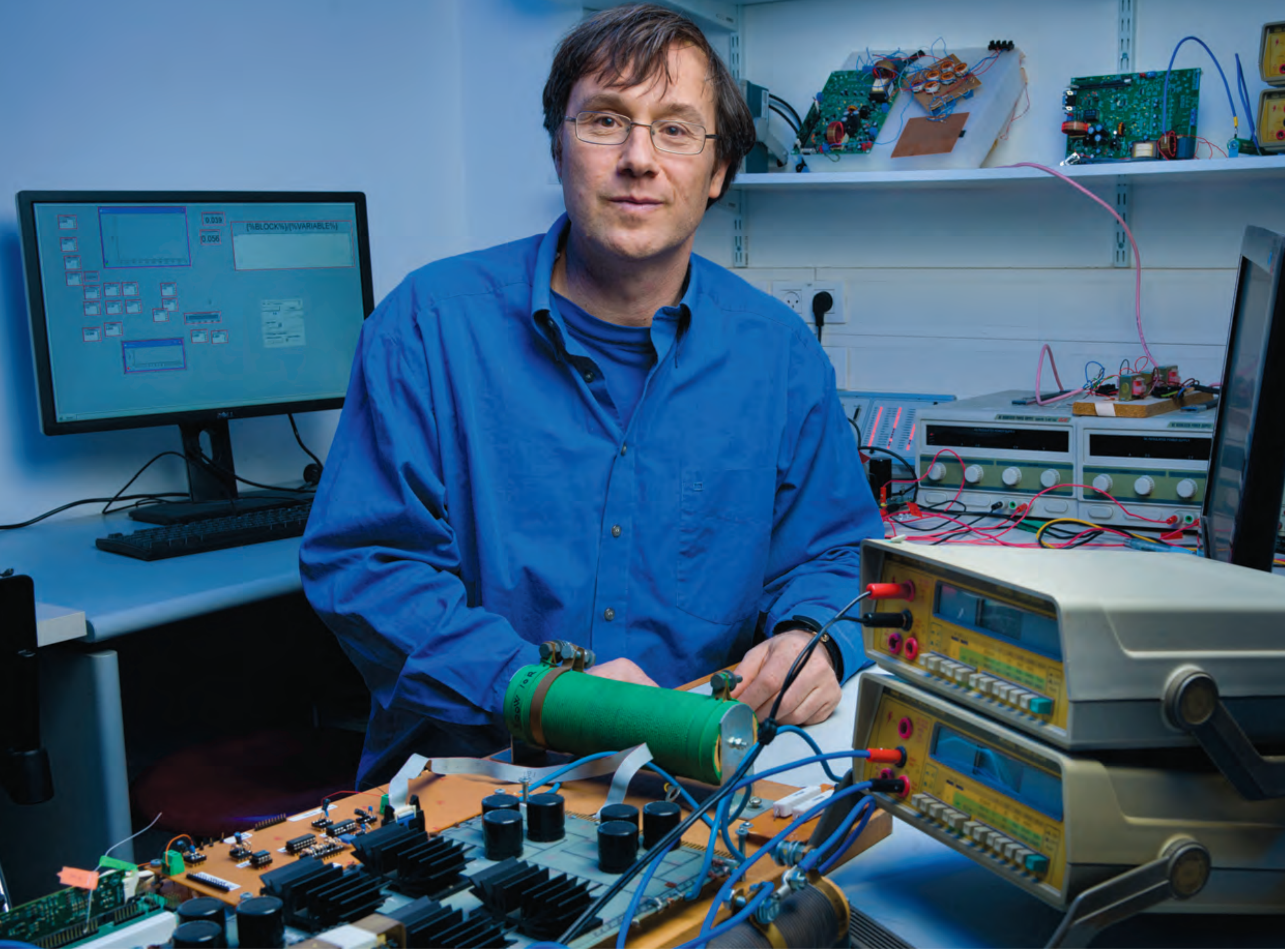
Prof. Avi Seifert: Harnessing the wind for our needs.

are too costly, requiring the support of a government that is environmentally aware and responsible, as is already the case in the field of solar energy.

Aerodynamic Trucks

Prof. Seifert is working on developing additional applications for active flow control. His group is involved in unique research aimed at reducing the aerodynamic resistance of large trucks that travel our highways. The rear section of these trucks is not aerodynamically designed, but is lopped off due to practical requirements for loading and unloading goods. Therefore, the smooth flow of air cannot occur, creating considerable resistance. In order to reduce resistance, scientists are embedding an active flow control system in the trailer, thereby increasing energy efficiency and significantly reducing fuel consumption and pollution. The development work requires a combination of basic research in the laboratory, and applied research in road trials and wind tunnels with model trucks. The hope is that within a few years, research will lead to a product with enormous environmental impact.

Prof. Avi Seifert heads the School of Mechanical Engineering, and is an international expert in low-speed aerodynamics and active flow control. His research focuses on energetic aspects of systems relating to airflow that affect the environment. Prof. Seifert has carried out experiments at NASA, served as vice dean for research in the Faculty of Engineering, and published more than 40 articles in international journals. He currently holds five patents and a number of others developed in his laboratory await approval.



Prof. Michael Margaliot: Creating the standard for connecting renewable energy sources to the grid.

"Electricity in traditional grids is produced by large generators known as synchronous generators," explains Prof. Weiss. "This long-established technology, based on moving mechanical parts such as a spinning rotor, generates electricity with specific features, and its stability control is designed to suit these features. Current control mechanisms rely on very complex algorithms developed over many years, which ensure that voltage and frequency levels are maintained within a certain range, not too high and not too low. Deviation from these levels is liable to cause malfunctions and serious damage to facilities and devices connected to the electricity grid."

Sources of renewable energy—solar farms, wind turbines, devices producing energy from waves—are based on technologies that differ completely from synchronous generators. They generate electricity by means of electronic switching converters, which convert energy to a form that is suitable for the grid. These converters, which are essentially electronic, have no moving mechanical parts, and the electricity that they generate has very different characteristics from that produced by synchronous generators. The increase in the relative share of renewable sources in the grid is liable to impact its stability. This is why electricity companies throughout the world are reluctant to connect too great a number of renewable energy sources to the grid. Researchers worldwide are looking for solutions to this problem.

To address this issue, Prof. Weiss and Prof. Margaliot have developed an electronic converter that imitates the way in which the synchronous generator

Stabilizing Force

Israel's residents enjoy a reliable and stable supply of electricity, 24 hours a day. The electricity grid in our country is a world leader in terms of stability, with very few minutes per year without electricity. However most of us are unaware that the stability of the national grid is not to be taken for granted: it involves highly sophisticated control mechanisms. Prof. George Weiss and Prof. Michael Margaliot of the Department of Electrical Engineering Systems in the Faculty of Engineering are developing a technology to enable the grid to maintain its stability, even as it is based more and more on renewable sources of energy.

works. The converter, called a synchronverter, is based on an innovative control algorithm that endows electricity produced by renewable energy flow with frequency and voltage properties similar to those of electricity produced in traditional fossil-fuel burning power plants. In this way, from the standpoint of the grid, there is no difference between the two types of electricity it receives. A renewable energy source connecting to the national grid by means of this converter can be integrated relatively easily, and uses existing mechanisms to control stability. In this way, it will be possible to significantly increase the usage of renewable energy, until electricity consumption will be entirely based on sustainable sources.

"We hope that our technology will become the standard for every converter connecting renewable energy sources to the electricity grid," sums up Prof. Margaliot. "This is an enormous global market that is growing at an extraordinary pace. As early as 2014 it is expected to reach a scale of 7 million converters and $8.5 billion."

Prof. George Weiss specializes in control theory and power electronics, focusing on controlling renewable sources for generating electricity. Until 2007 he was a member of the prestigious control and power systems research group at Imperial College in London. Prof. Weiss has published over 100 articles and one book, and has served as scientific adviser to renewable energy companies in Israel and worldwide.

Prof. Michael Margaliot specializes in optimal and geometric control, and the stability theory of dynamic systems. Prof. Margaliot has published more than 40 articles and two books.

Prof. Emanuel Peled conceived a revolutionary idea: a cell operating on sodium and air.

"There are many ways to harvest energy from renewable resources, but they share a common weakness: renewable sources of energy appear irregularly. There are sunny days and overcast days, the wind blows hard or gently…" explains Prof. Peled, who has developed fuel cells at Tel Aviv University for 30 years. "Therefore, in order to finally put aside oil, coal, gas, and nuclear energy in favor of a cleaner environment, we must make harvesting renewable energy stable and economically viable. The key lies in developing cheap, efficient means of storing energy. Batteries today cannot meet this requirement because they are too expensive and their lifespan too limited. Reversible fuel cells, on the other hand, offer a promising solution for storing sustainable energy."

Fuel Cells

How do fuel cells operate? Like batteries, fuel cells store energy in chemical form, converting it to electricity when needed. But there are marked differences between the two: fuel cells have a significantly longer lifespan than lead or lithium batteries, owing to lesser physical deterioration of chemicals. How is this achieved? Chemicals in fuel cells are stored *outside* the main cell unit, in liquid or gas form, unlike solid-state electrodes situated *inside* the battery pack. Chemicals in fuel cells are cheaper than those used in batteries. At the heart of the fuel cell is a unique membrane developed (along with a method for its industrial production) in Prof. Peled's laboratory, which provides minute particles selective passage between electrical poles when generating electricity. These factors increase the economic feasibility of fuel cells for wider use, and Prof. Peled's group is developing cells intended for various applications, using different chemicals.

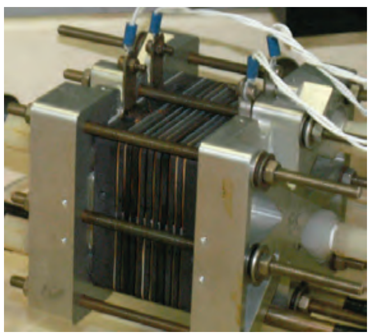
A reversible fuel cell intended as the base unit for a large energy supply, such as a power plant,

Saving for a Rainy Day

How can we store energy produced from renewable, natural, clean sources such as the sun and wind over time? This problem engages scientists the world over. The laboratory of Prof. Emanuel Peled, School of Chemistry, has been developing a revolutionary, cheap, and efficient solution: reversible fuel cells. To date, the group holds 10 patents and a number of world records in the electrical output of fuel cells.

uses bromic acid and hydrogen gas. Another cell, for mobile electronic devices, is fed by methanol. And in the field of electric cars, Prof. Peled has conceived a revolutionary fuel cell, which operates on sodium and air, competing successfully with lithium-air cells currently being studied around the world as the next generation of electric car batteries. Both sodium and lithium cells grant the electric car a range of 500 km per charge, three times today's range. But sodium enjoys significant advantages over lithum: it is cheaper and more available, and resistant to a greater variety of materials, offering savings in packaging and electrodes. In the final analysis, the sodium-based cell should cost half the price of the lithium-based cell, while its performance—according to research in Prof. Peled's laboratory, which has patented the innovative cell—will not fall below that of its popular rival.

Having proven the economic and practical feasibility of the fuel cell, Prof. Peled's group is currently working on improving electrode structure and quality of flow in the cell, to further reduce operation costs. If they succeed, it is possible that in a few years' time the concept of the battery will be forever redefined.



Fuel cell for storing wind and solar energy.

Fuel cell developed in Prof. Emanuel Peled's lab, operated by methanol and capable of powering a small laptop computer.

Prof. Emanuel Peled, School of Chemistry, is a world-renowned researcher of fuel cells and batteries. He was a founder of two start-ups, Chemtronics and EnStorage, based on technologies developed in his laboratory. His group has developed unique fuel cells that have achieved world records in electricity output. Prof. Peled was head of the Wolfson Center for Applied Materials Research at Tel Aviv University, and director of the knowledge center for fuel cells and batteries of the Ministry of Science and Technology. He has published more than 150 articles, registered over 40 patents, and won prestigious awards in Israel and worldwide.

INTRODUCING...BLUE ENERGY

Scientists around the world are searching for different types of green energy—clean energy from natural, sustainable sources. But Prof. Nathan Nelson, Department of Biochemistry & Molecular Biology, suggests taking our sources of energy one step further, to generate blue energy, which emits nothing but water into the atmosphere when utilized, and therefore produces zero pollution. His pioneering research has recently been awarded a prestigious grant from the European Union Research Council (ERC).

"The problem with green processes for generating energy is that although they reduce pollution, they do not do away with it altogether," explains Prof. Nelson. "Even if we fill up our car with organic fuel generated from corn, there will still be a combustion process in the engine emitting molecules of carbon dioxide—a combination of carbon (C) and oxygen (O)—into the air. Although the quantity of CO_2 emitted is equal to the quantity absorbed by the plant from the air during the photosynthesis process, other actions that emit CO_2 are required in order to grow the plant and produce fuel from it, such as fertilization, harvesting, transport. The carbon balance will always be negative. The bottom line is that accepted processes for producing energy are not sustainable. At some time in the future, all organic fuels used by humankind will run out. In our research, we are trying to find an efficient way of producing the only sustainable fuel in the world—hydrogen (H_2). Burning this kind of fuel will connect the hydrogen molecules (H_2) to oxygen (O) and will emit molecules into the atmosphere that contain no carbon dioxide—molecules of H_2O, or in other words—*water!* This is the essence of blue energy: a sustainable source of energy that is not expendable and does not cause pollution. We intend to achieve this goal by genetic manipulation of an existing organism in which the process of photosynthesis takes place."

Photosynthesis

Photosynthesis, the wonderful process by which plants convert the energy of sunlight into chemical energy stored in organic molecules (glucose), is the focus of many studies. One of the unique characteristics of photosynthesis is the splitting of the water molecule—considered to be one of the most stable in nature—into its two components: oxygen and hydrogen. Oxygen is emitted into the air, and hydrogen is used to build glucose molecules (sugar) that are the backbone of organic matter making up the living cell. In fact, the process of photosynthesis is the source of oxygen in the atmosphere, of a large part of organic matter and food in nature, and of the majority of life forms on earth. Photosynthesis is responsible for both plant and fossil fuels—coal, oil, gas, wood, and ethanol.

Genetic Engineering

Prof. Nelson has conducted basic research on cell membrane processes for 40 years. He has conceived a revolutionary idea: intervening in the photosynthesis process of a microorganism to cause it to generate hydrogen molecules, as a source of blue energy that is totally clean. For the purposes of his research, he has chosen a unicellular bacterium called Synechocystis, from the blue bacteria (cyanobacteria) group, a primitive organism that carries out photosynthesis and generates hydrogen. The problem is that in and around the cell, hydrogen molecules meet oxygen molecules emitted in the photosynthesis process, and oxygen holds back the process of

Prof. Nathan Nelson intervenes in the photosynthesis process of microorganisms to generate blue energy.

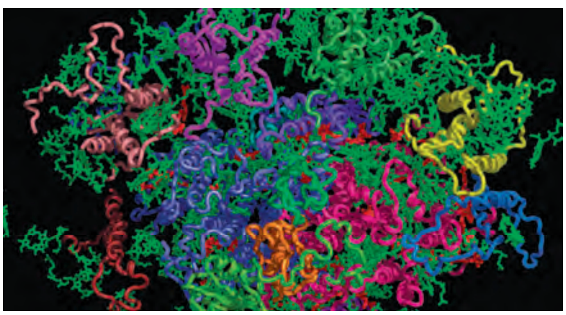
producing hydrogen, even joining up with it to produce water.

In order to store clean hydrogen gas that can be used as fuel, it is therefore essential to prevent the encounter between hydrogen and oxygen. To this end, Prof. Nelson proposes alternately halting the release of oxygen from the water in photosynthesis. In this way, hydrogen will be produced without oxygen, and it will be possible to collect it in containers.

How can this be done? First of all, researchers will perform a genetic manipulation to enable gathering hydrogen ions (H+) and electrons formed in the processes of photosynthesis and respiration of the cell, in order to form them into hydrogen molecules (H_2). At the same time, another genetic engineering process will cause the process of releasing oxygen in the bacteria to be sensitive to temperature, so that at a relatively high temperature the water molecules will not split and release oxygen. The engineered organisms will constantly flow between two temperature environments: an environment of 30°C enabling the production of oxygen and of organic matter essential for the cell's existence, and a 40°C environment preventing the production of oxygen, thus allowing storage of the hydrogen. A third genetic manipulation will accelerate the rate of production of hydrogen in the cell, and make the entire process more efficient. Blue energy formed in this way will create no pollution.

"The solution sounds promising, but we are just at the outset," says Prof. Nelson. "This basic research could even take as long as a decade. The work is likely to develop in different directions and produce discoveries that no one can anticipate in advance. Only one thing is certain: a lot of fascinating discoveries await us along the way!"

Prof. Nelson discovered the structure of PS1, a complex involved in photosynthesis—the most efficient nano-photochemical machine in nature.



Prof. Nathan Nelson is an expert in biochemistry and molecular biology, with an international reputation in basic research into cell membrane molecule proteins and complexes. He has won prestigious awards in Israel and abroad, and is a member of EMBO—the European organization for excellence in life sciences. He has served as president of the Israel Society for Biochemistry & Molecular Biology, and as director of the Daniella Rich Institute for Structural Biology. Prof. Nelson has published more than 240 articles, and his work has been cited over 15,000 times in articles by researchers worldwide. In 2011 his research was awarded a grant from the European Union Research Council (ERC).

GROWING OUR SAVINGS

Plants are an excellent source of naturally available, clean energy. Scientists hope that within 25 years fuel produced from plants will supply 30% of energy needs. Nonetheless, the road to the future is long, and current processes for producing energy from plants are not sufficiently efficient. In Prof. Shaul Yalovsky's laboratory in the Department of Molecular Biology & Ecology of Plants, genetically modified plants are grown for efficient production of biofuel.

"Plants utilize the sun's energy naturally in the photosynthesis process," explains Prof Yalovsky. "The plant absorbs energy from sunlight and uses it to create sugars from water and carbon dioxide gas (CO_2). Most of these sugars are stored in plant cell walls in the form of a polymer called cellulose. From cellulose we can produce a biological fuel called ethanol. In Brazil, for example, about 30% of fuel consumed originates in ethanol from sugarcane. In other places, ethanol is made from starch produced from corn. The production of fuel from these plants is relatively easy, yet it will not be possible to rely on them over time because they require special growing conditions (much water or fertile soil), and they also represent important sources of food for the world's population. Another problem is that the processes in use today for producing cellulose from plant tissue are not efficient, meaning that the energy produced does not justify the quantity of energy expended in the process. In my laboratory, we have discovered a group of proteins that could make the production of cellulose significantly more efficient, and we hope to adapt the method to plants that are easy to grow and have a high potential for future production of biological fuel."

Prof. Yalovsky's research is particularly important because increased efficiency in cellulose production is of enormous economic significance. In 25 years' time, when it is forecast that plants will provide 30% of world energy needs, an improvement of even 1% in the production process will save billions of dollars! Today, the cost of 30% of energy consumed each year in the United States alone is $600 billion. One percent of that means no less than $6 billion!

Genetic Engineering

Prof. Yalovsky's research team focuses on the stalk, which in many plant species is the main source of cellulose. In order to produce cellulose from the stalk, it must first be separated from another component of the stalk cell—lignin. Chemical methods of separation cause a cellulose loss of 50%. Scientists assume that reducing the quantity of lignin in the stalk through genetic engineering will make the production of cellulose cheaper and more efficient.

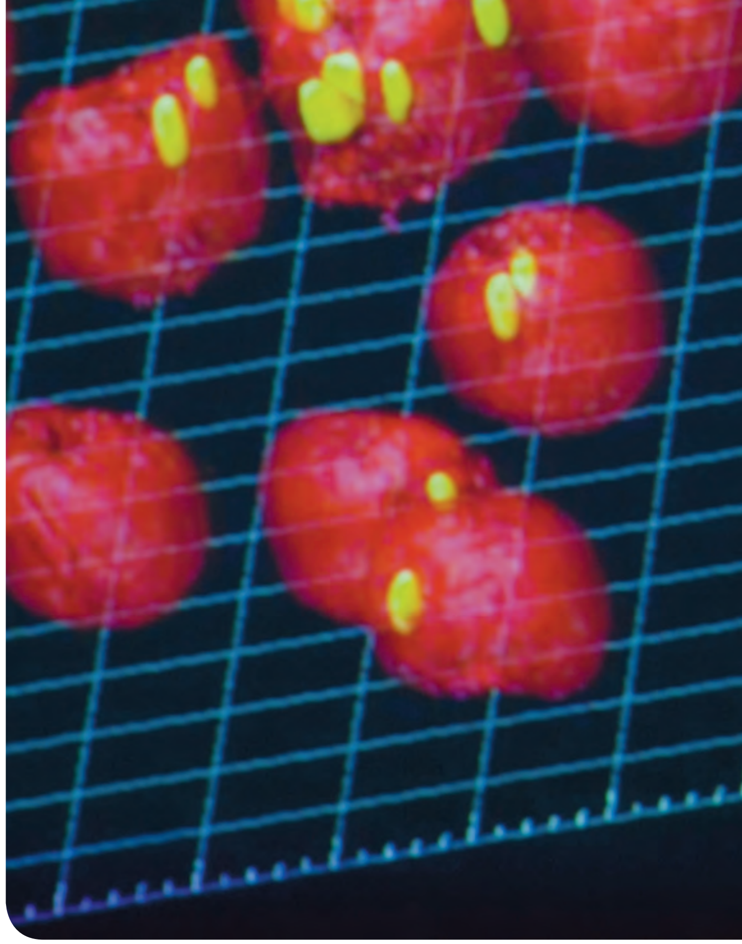
How does one grow a plant with less lignin? In the first stage, researchers identified proteins that control the level of lignin in the cell wall. These proteins operate like a switch, with which it is possible to turn on or off the process of lignin production. With genetic engineering they changed the action of the proteins and turned them into switches that are permanently off, or alternatively, permanently on. Afterwards they implanted the altered proteins in a laboratory plant called *Arabidopsis* (thale cress) and monitored its development. Researchers discovered that when protein action is reduced or stopped (when the switch remains off) the level of lignin in the plant increases. And when a constantly active protein (when the switch

Prof. Shaul Yalovsky: "Making cell production more efficient has enormous economic significance."

remains on and cannot be turned off) is implanted in the plant, lignin production in the cells is reduced and the desired plants develop—plants with a reduced quantity of lignin!

In the next stage, researchers will implant the altered proteins into plants with a high potential for producing fuel in the future. "Throughout the world scientists are looking for plants for this purpose, plants that are both easy and cheap to grow, and at the same time do not compete with agricultural crops," says Prof. Yalovsky. "These are plants that are not used for food or clothing, and that can grow in marginal soil, poor in nutrients and water, and unsuitable for agriculture. This is due to the understanding that production of fuel from agricultural crops, such as sugar beet or corn, is likely to produce competition that will be economically and socially disastrous." The first plants to be examined in the laboratory will be leafy species from the cereal family. Researchers will determine whether genes they have discovered are able to reduce lignin in these plants. Improved leafy species with a mutation for reduced production of lignin are likely to make the production of biological fuel significantly more efficient, saving the world economy billions of dollars.

Prof. Shaul Yalovsky is a world-renowned researcher in the molecular biology of plants. He studies the cell-signaling processes that control cellular differentiation and growth, and plant development. Prof Yalovsky has published key articles in eminent journals and frequently lectures at international conferences and serves on panels of national and European research foundations. Prof Yalovsky edits leading journals in the fields of plants and plant-cell signaling.



Dr. Yuval Ebenstein: "Algae produce high-quality fuel and can be grown

FILL 'ER UP... WITH ALGAE OIL

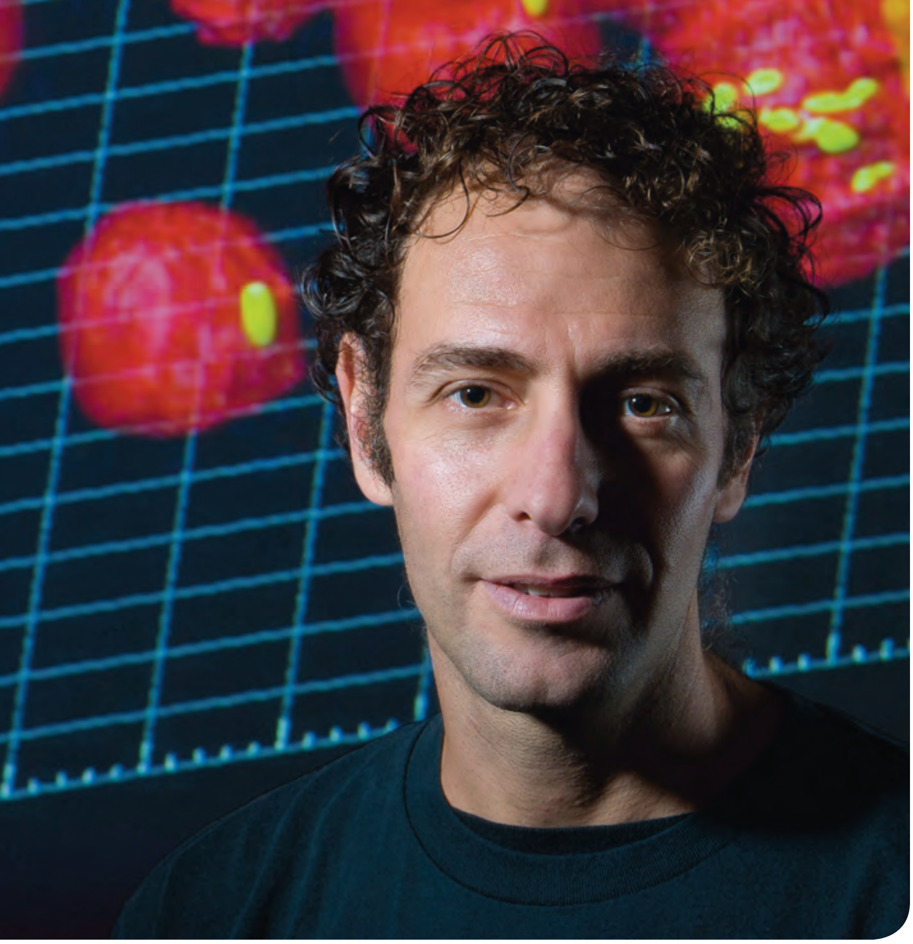
Biodiesel, the natural fuel produced from corn, has already become a household term, and is considered the next great thing by many environmental groups. Yet Dr. Yuval Ebenstein and Dr. Yael Michaeli of the Department of Chemical Physics prefer to produce fuel from... algae! These ancient forms of marine life offer a promising source of energy with considerable advantages.

"Biodiesel is fuel naturally produced by plants and organisms. Many see it as a green alternative to today's expendable fuels," says Dr. Ebenstein. "At present, the majority of biodiesel on the world market is produced from corn. But corn crops for fuel compete with food crops. Many farmers prefer to grow corn for fuel because of its profitability, which could lead to a food shortage. Algae are not food. They produce high-quality fuel, almost ready for combustion, and can be grown in areas unsuitable for agriculture, such as the desert. Moreover, quantities of algae can be grown in high stacks of containers that do not require much space, unlike field crops."

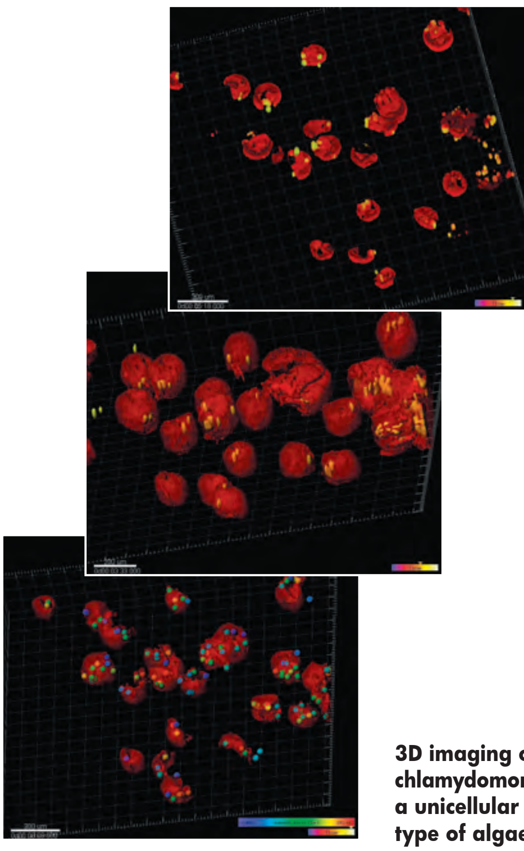
The algae studied are unicellular organisms capable of creating and storing natural oil in a quantity up to 60% of their dry weight. This oil is produced by the algae when under stress as a survival mechanism—a kind of energy store for times of shortage, very similar to fat stores in the human body. Properties discovered in the laboratory are promising: biodiesel produced by algae can power a car practically as is, without costly, polluting processing. So how can we produce a sufficient quantity for commercial use? This is the challenge facing the research team at Tel Aviv University today.

Proteins for Fuel Production

To make the process of generating oil in algae more efficient, researchers are developing in-depth understanding. They systematically alter parameters in the growing environment such as nutrition, temperature,



in areas that are unsuitable for agriculture."



3D imaging of chlamydomonas, a unicellular type of algae.

cycles of light and dark, and the supply of essential materials nitrogen and iron, and examine optimal conditions for creating the maximum quantity of fuel. Advanced optical imaging technology allows close monitoring of oil accumulation in the cell in real time. The oil is colored, making it is possible to identify the quantity formed, and the place where it is concentrated within the cell.

Together with visual imaging, scientists seek to understand what occurs in the cell at the biological and genetic levels. To do so, they use a genetic analysis method called RTPCR (real-time polymer chain reaction). This method measures quantities of types of RNA found in the cell at a given time, helping researchers to identify proteins related to the fuel production process. Dr. Ebenstein explains: "RNA is genetic material that is a recipe for creating proteins in a cell. A high level of a particular type of RNA indicates that the cell is making an effort to create a matching type of protein, in response to a change that we have made to environmental conditions. In this way, we identify proteins whose level increases significantly in response to specific environmental conditions, encouraging the production of fuel. Proteins identified as being significant in the oil production process are examined in depth, including genetic manipulations intended to increase output." In the future, scientists hope to move out of the laboratory and partner with industry to promote commercial production of biological, algae-based fuel.

Dr. Yuval Ebenstein is a promising young scientist who returned to Israel in 2011 as part of Tel Aviv University's effort to bring Israel's best and brightest home. Dr. Ebenstein specializes in physical chemistry and biophysics, and developed innovative optical technologies for reading genetic information at UCLA. He was awarded a Rothschild scholarship and the prestigious international Human Frontiers Fellowship, and has published 20 research studies in leading journals. On his return to Israel, he received the Israel Science Foundation Morasha Prize, and has used the award to set up an advanced biophysics laboratory, equipped with a range of unique microscopes—the result of innovative developments by Dr. Ebenstein himself.

Foresight, Planning & Management

Electric cars, photovoltaic (solar) cells, and thermosolar power plants—all of these could be feeding electrical outlets in our homes in a number of years. According to research by Prof. Asher Tishler, Dean of the Faculty of Management, this vision can become reality only if we learn to manage and plan the research, development, and operation of relevant new technologies.

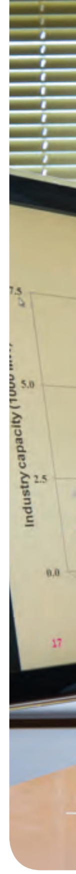
"Air pollution caused by emissions of carbon dioxide (CO_2) and other gases from combustible fuels is an acute problem in Israel," explains Prof. Tishler, who has been researching energy economics for 30 years. "Beyond environmental damage, pollution damages Israel's standing as a member of the OECD (Organization for Economic Cooperation and Development), which requires member nations to report steps they are taking to protect the environment. If we do not further the use of clean energy soon we are likely to suffer economic isolation as a response from the OECD. Given Israel's limitations, the solution can be found primarily in switching to solar energy and electric cars. But this is not simple: present technology is not advanced enough and is too expensive to operate; and the structure of an electricity network that relies on renewable energy sources has not yet been formulated, and is complicated to manage."

Planning Ahead

Prof. Tishler is researching an intelligent plan for Israel's electricity system for the years 2015-2050. Using mathematical models, he examines how to manage and efficiently build an electricity system that integrates renewable energy sources. The overwhelming conclusion of his research to date is that the Israeli government must allocate resources for R&D of green technologies. Prof. Tishler maintains that private companies will not take on this critical task—the research is simply not profitable as it produces knowledge that is essentially public property. Only significant technological improvements with government support will enable the country to plan and build a national electricity grid that will, in large part, be solar and clean.

Israel must invest in developing solar technologies that will reduce the cost of photovoltaic cells and thermosolar power plants. Only a significant reduction in cost that comes in the wake of development will gradually increase use of innovative technologies. Furthermore, we need R&D of advanced, efficient methods for large-scale electricity storage. In the future electricity system, a large portion of which will be solar, there will be a substantive problem: electricity production drops significantly at night and on overcast days, mainly in winter. Newly developed technologies would help the system store electricity generated in sunny times.

Alongside technological developments, Prof. Tishler and other academics in Israel and worldwide also propose various smart-planning solutions. A particularly interesting and creative idea involves electric cars, themselves small power plants with fairly large batteries, which could be used to store energy for a national, largely solar, electricity system. Thus,



Prof. Asher Tishler: Wise planning and management makes the difference between a good idea, and an essential difference in quality of life.

in another 15 years when Israel is expected to have some 200,000 electric cars, it would be possible to use car batteries as backup for periods of peak electricity demand. This smart method would preclude the construction of two polluting power plants, but its implementation depends on suitable preparation: planning an economic model that will encourage the participation of electric car owners through financial incentive.

In addition, Prof. Tishler believes in the establishment of flexible electricity rates that change over the course of the day and the year, reflecting the overall marginal cost of producing and distributing electricity. These differential rates already exist in Israel but lack sophistication. They must account for the cost of environmental damage caused by electricity production using coal and gas, and encourage electricity production using solar and other renewable energy technologies.

These and other intelligent solutions are the results of research in business administration. This sphere is essential for technology developers who are discovering that innovative, smart, and superior technology is not always enough: advantageous use of technology also means finding and maintaining appropriate markets. Success depends upon efficient production, correct market structure, intelligent rates, suitable market entry, continuity of R&D, and sustained empowerment of the entity developing the technology. The developing body must be designed correctly and managed well. It must promote its human capital, and become integrated into the markets in which it operates.

Intelligent and wise planning and management is the difference between having a good idea and making an essential difference in quality of life.

Prof. Asher Tishler is an expert in business administration, and serves as the dean of the Faculty of Management and director of the Eli Hurvitz Institute for Strategic Management at Tel Aviv University. His research includes energy and defense management economics, R&D, and research methodologies. Prof. Tishler has published over 100 articles in academic journals. He has served and presently serves as a member of energy and defense forums, and has been a consultant to various bodies in Israel and overseas, including the IDF and Ministry of Defense, Ministry of Finance, and Ministry of National Infrastructures, as well as banks and companies in the industrial, service, and high-tech industries.

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