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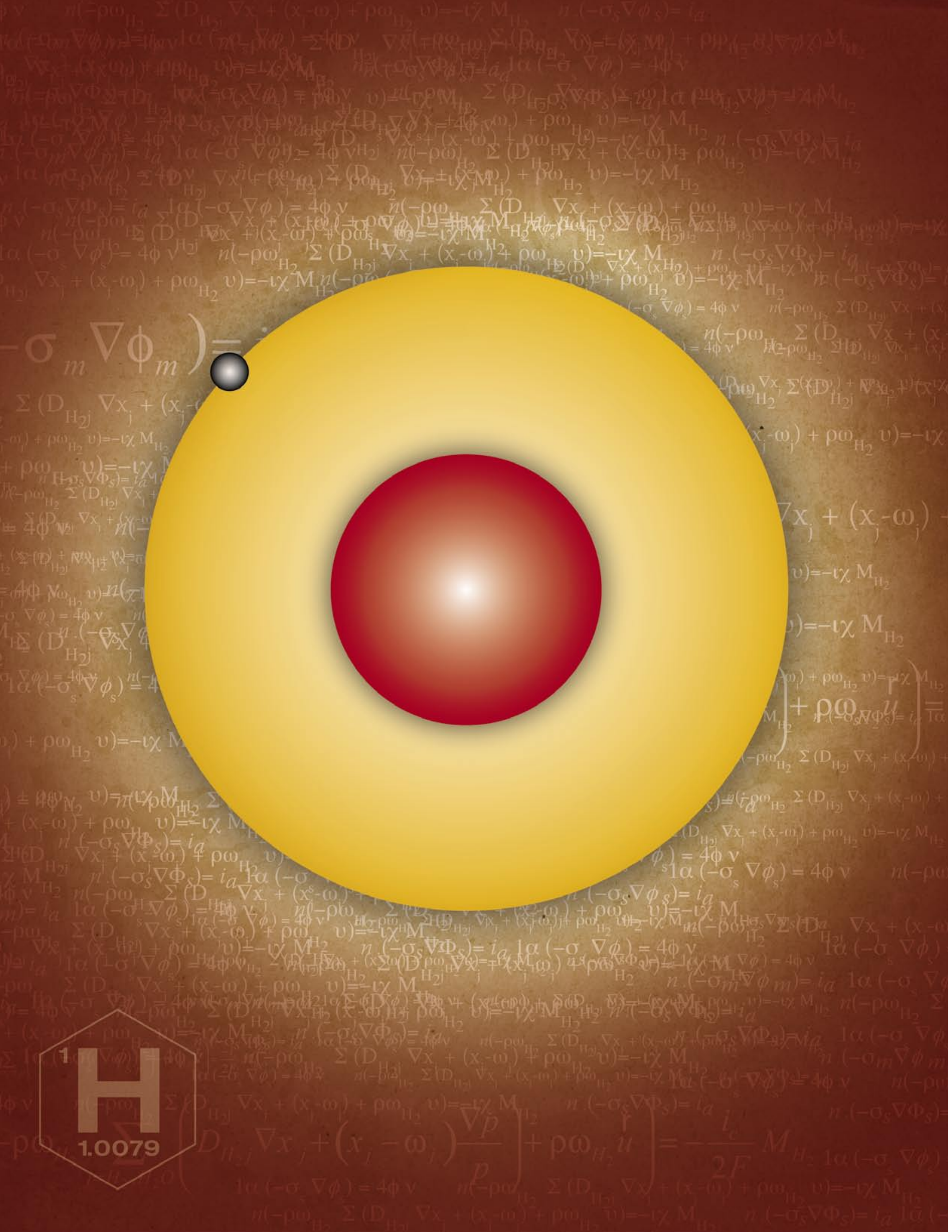


The Hydrogen Fuel Equation

Hydrogen may be the fuel of the future, but myriad research challenges must be addressed before its potential is realized. UNLV science and engineering faculty are leading the effort to harness the power of nature's most abundant element

Story by Tony Allen

Consider, for a moment, the simple hydrogen atom.

It is the most abundant atom in the universe. It is contained in every living organism and in virtually everything we touch. It's in our bodies, in wood, in plastic, and in water.

But rarely is hydrogen found isolated in nature.

And there's the rub for researchers seeking a way to produce hydrogen fuel for mass consumption.

Considered by many the "holy grail" of alternative energy, hydrogen fuel is currently the buzz, garnering extensive media attention, attracting interest from private industry, and even earning mention in the President's State of the Union Address. In academe, study has been under way for some time at research universities throughout the country, including at UNLV, with the goal of producing new hydrogen fuel technology that will diminish or eliminate our dependence on fossil fuels.

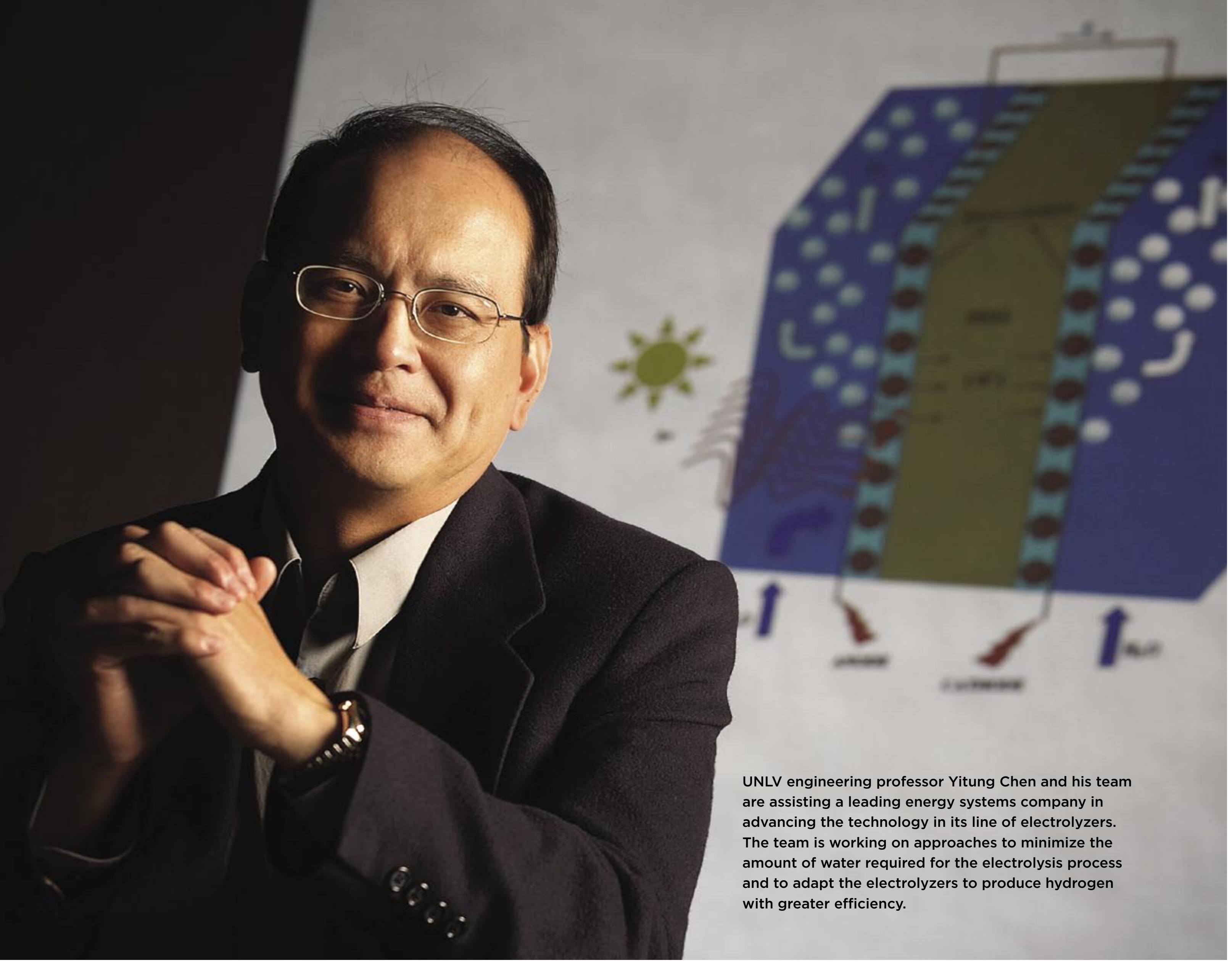
At UNLV researchers are tackling every stage of the hydrogen fuel equation, including not only production of hydrogen, but also storage, transport, and use.

"UNLV continues to perform significant research directed at making a hydrogen-based economy possible," says Dr. Eric Sandgren, dean of the Howard R. Hughes College of Engineering. "There are significant challenges that need to be addressed in order for this to happen, and our faculty and students are actively engaged in meeting those challenges."

UNLV researchers have received millions of dollars in federal grants and appropriations from the Department of Energy and other agencies in recent years to discover ways to access this source of energy, which is increasingly being recognized as the fuel of the future.

"Our research on hydrogen fuel attracts external funding critical for the support of UNLV graduate students, scientific equipment and facilities, and undergraduate research initiatives," says Dr. Ronald Yasbin, dean of the UNLV College of Sciences. "The scholars and scientists are teaching undergraduates, mentoring graduate students, and spending countless hours in laboratories and research facilities to preserve, protect, and improve our quality of life – not only in Southern Nevada, but for all our citizens."

The challenges associated with hydrogen fuel research are myriad, however. UNLV science and engineering faculty are involved in a number of projects – many involving the use of solar power to help advance hydrogen technology – that are designed to solve various intricate problems in this emerging field of research. Some highlights of major projects currently under way are outlined below.



UNLV engineering professor Yitung Chen and his team are assisting a leading energy systems company in advancing the technology in its line of electrolyzers. The team is working on approaches to minimize the amount of water required for the electrolysis process and to adapt the electrolyzers to produce hydrogen with greater efficiency.

PHOTOGRAPH: AARON MAYES

Utilizing Solar Energy

Engineering professors Robert Boehm, Yahia Baghzouz, and Yitung Chen, as well as postdoctoral fellow Suresh Sadineni, 10 graduate students, and one undergraduate, are working with the Las Vegas Valley Water District (LVVWD) in the development of hydrogen-powered vehicles – both fuel cell and internal combustion types – and a hydrogen fueling station.

The researchers are utilizing solar energy to produce hydrogen through the process of electrolysis. In electrolysis, electricity – in this case from photovoltaic, or solar, cells – is used to separate the hydrogen and oxygen. The hydrogen is then pumped into the fuel cells, where it mixes with oxygen to create energy and power the vehicle.

As part of the project, UNLV is assisting in the development of a hydrogen fueling station for the LVVWD. Researchers are utilizing different approaches to the employment of the electrolysis process to develop cost-effective hydrogen reserves. The hydrogen will then be used to fuel custom-designed vehicles for the LVVWD motor pool.

In a related study, Chen, Sadineni, and a team of students are assisting Proton Energy, a leading energy systems company, in advancing the technology in its line of electrolyzers. The team is working on an approach to minimize the amount of water required for the electrolysis process; they are also researching how electrolyzers can be adapted to yield optimal performance.

Additionally, Chen and engineering professor Samir Moujaes, along with research professors Sean Hsieh and Roger Rennels, are studying solar-powered thermochemical production of hydrogen. This project involves use of a closed chemical reaction cycle in which only water and solar thermal heat are applied, resulting in the splitting of water to produce hydrogen gas. The project team, which includes three national laboratories, two other universities, and a San Diego company, recently won one of three research awards presented by the Department of Energy.

Improving Performance

UNLV researchers are also working to make fuel cell vehicles less expensive and simpler in form. Although fuel cells utilizing hydrogen fuel are very efficient, researchers are working to configure systems that combine internal combustion engines with fuel cells to offer more effective performance. Included in this work is the use of direct injection of hydrogen into the cylinders of internal combustion engines.

Direct-cylinder injection of fuel, a process similar to that used in diesel engines, is one intermediate approach that allows for use of hydrogen in engines that contain, in large part, existing technology. This offers the possibility of improving performance and decreasing emissions.

This approach is guiding the work of a group of engineering students who are converting a water district utility vehicle, powered by an internal combustion engine, to use hydrogen fuel instead of gasoline. The engine, which is being developed with the assistance of Las Vegas-based Kells Automotive, is using the direct injection concept.

In a related study, Baghzouz and his team are converting an internal combustion engine pickup truck used by water district meter readers into a hydrogen-powered vehicle with both direct cylinder injection and fuel cell technologies. The fuel cell will be used to power the vehicle's electronic components, while a hydrogen-powered internal combustion engine provides the acceleration power.

Simplifying Hydrogen Generation

Mechanical engineering professor Yitung Chen and two graduate students are working with the Southern Nevada division of the England-based Hydrogen Solar, Ltd. to simplify the generation process of hydrogen from electrolysis. In conventional electrolysis using solar power, sunlight is converted into electricity in solar cells. Then the electricity generated is used to power the process that separates hydrogen from water. The new technology, described as the "tandem cell" by Hydrogen Solar, essentially combines the two processes in an enhanced solar cell.

Consisting of several layers of materials, tandem cells use sunlight directly to generate hydrogen and oxygen from water. A special electrolyte solution flowing through the cells is a key element in the performance of the system. Chen and his team are analyzing this process using advanced computational models to determine the most effective design.

A Lesson on Hydrogen Fuel Issues

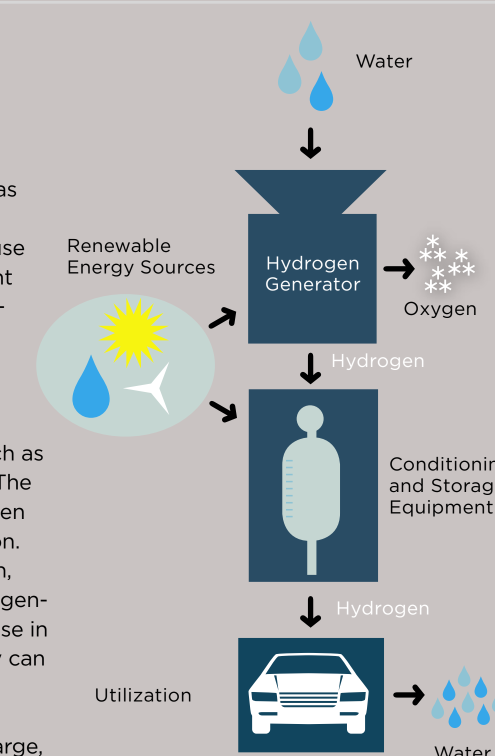
Because hydrogen is not common in an isolated form, it must be extracted from other materials in order to become useful as a fuel. Currently, the most common and inexpensive form of hydrogen extraction involves steam methane reforming, during which natural gas and steam are heated to remove usable hydrogen.

The problem is that fossil fuels are used to create it, and greenhouse gases are released into the atmosphere as a result. Hence, a significant challenge is to find another hydrogen production process that is cost-effective and friendlier to the environment.

Scientists and engineers are currently examining ways to extract hydrogen from various materials, often utilizing renewable energy to "split" water into hydrogen and oxygen. Through a process called electrolysis, electricity generated from renewable energy sources, such as wind and solar power, is used to separate the hydrogen and oxygen. The hydrogen is then pumped into the fuel cells, where it mixes with oxygen to create energy and power a vehicle. Water vapor is the only emission.

A major challenge is to lower the cost of hydrogen fuel production, therefore making it more attractive and economical to utilize in hydrogen-powered vehicles. A related issue is how to increase efficiency of its use in automobiles to enable cars to go as far on a tank of hydrogen as they can on a tank of gas.

Also at issue is the storage of hydrogen fuel for everyday use. Currently, the most common method for hydrogen storage requires large, high-pressure tanks that contain fairly small amounts of the element. Careful design approaches must be used to ensure safe use in vehicles; this includes assuring passenger well-being in the event of car crashes. Thus, researchers continue to seek safer, smaller, and more convenient hydrogen storage for use in cars.



Hydrogen Production Using Renewable Energy

Surface Science

The best way to increase the efficiency or operation of any device is to analyze how it works. UNLV chemistry professor Clemens Heske and a team of 10 post-doctoral scholars and students are working to better understand solar cells, photoelectrochemical cells (like the tandem cell), fuel cells, and electrolyzers on the most basic, atomic levels. This, in turn, will help to explain and optimize the processes that result in hydrogen production.

By utilizing technologies and equipment available only at UNLV – and by performing experiments at high-brightness X-ray sources around the world – Heske and his team work to analyze the surfaces and interfaces of materials, which will enable manufacturers to develop more efficient products.

By examining the interfaces between layers of different materials, they can identify the chemical interactions that take place and seek to discover barriers that may hinder the flow of electrical current across the interface. Then they offer suggestions as to how to improve the products.

The expertise of Heske and his team is being sought out by universities and corporations throughout the world. They collaborate with numerous organizations, including the University of Delaware, the University of Hawaii, the National Renewable Energy Lab, the Florida Solar Energy Center, and Altairnano in Reno.

Another project in the College of Sciences, led by chemistry professors Balakrishnan Naduvalath and Heske, involves a combined theoretical and experimental approach to hydrogen fuel research, emphasizing the interaction of hydrogen and other materials on a fundamental level.

‘Blossoming’ Technology: Educating the Public Through Art


Mechanical engineering professor Daniel Cook

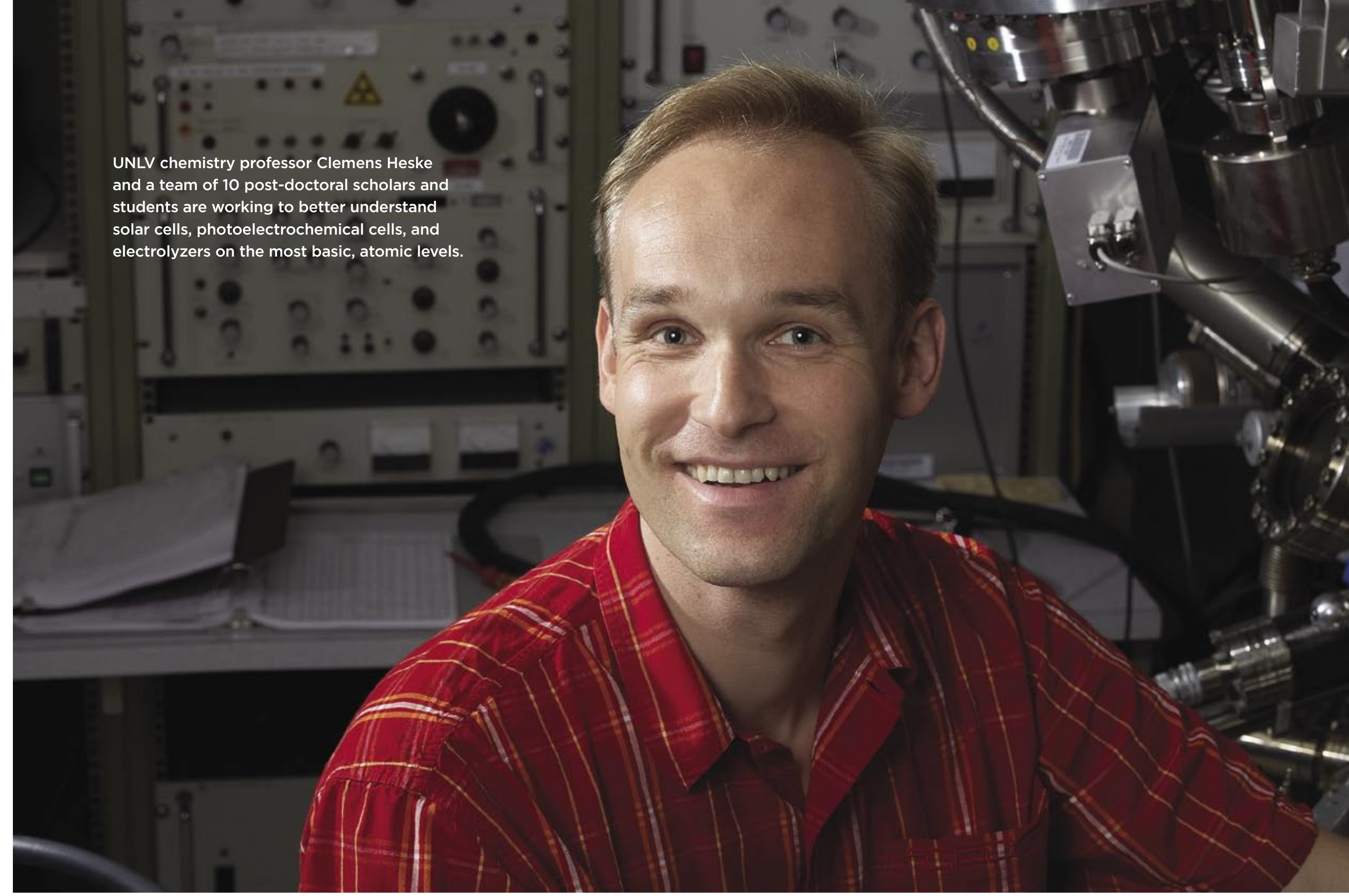
Spreading the word about solar and hydrogen power is the goal of Daniel Cook, a mechanical engineering professor who teaches courses in entertainment engineering and design at UNLV. He has created a way to use animatronic technology to educate citizens about the potential of solar and hydrogen energy.

“People don’t realize that the potential for solar energy in Southern Nevada is greater than anywhere in the world,” Cook says. “In fact, the raw solar energy flooding into Las Vegas is equal to the output from 55 nuclear power plants.”

To illustrate this point, Cook has designed a series of sculptures that mimic flowering plants, using solar cells and hydrogen to power the moving pieces. During the day, solar cells will act as “leaves” to absorb the sun’s energy and produce electricity. The electricity will be used to generate hydrogen through an electrolyzer, which then powers fuel cells to open and close the leaves of the plant. Excess hydrogen will be burned in a small flame, representing the flower’s pistil. When completed, the flower sculptures will be located on UNLV’s campus, as well as at various elementary and high schools throughout Southern Nevada.

“Even people who are well informed about different aspects of green energy systems do not necessarily understand how photovoltaic and fuel cells work,” says Cook. “This project breaks down the solar-power generation process and equates it to the elementary process of photosynthesis. The bottom line is that if we want people to utilize new technologies, we have to explain in layman’s terms how they work and their benefits.”

COOK: AARON MAYES; HESKE: GERI KODEY


UNLV chemistry professor Clemens Heske and a team of 10 post-doctoral scholars and students are working to better understand solar cells, photoelectrochemical cells, and electrolyzers on the most basic, atomic levels.

The project, called “FCAST” (for fuel cell and storage technology), examines the chemical bonding that occurs between hydrogen and potential storage materials. The researchers also study the intricate details of scattering processes between hydrogen molecules and atoms. In close interaction between experiment and theory, the FCAST project seeks to increase storage capacity and improve hydrogen utilization.

Employing Nuclear Power

UNLV researchers are examining equipment components used in a process that involves nuclear power to split water and extract its hydrogen, according to Tony Hechanova, project manager in the Harry Reid Center for Environmental Studies. He is leading a team of both engineering and science faculty in this research effort.

The team is exploring the design of a component called a “heat exchanger” that is used to transfer heat from a nuclear reactor to a chemical reaction from two different acids. When water is introduced to the chemical reaction, it splits, producing hydrogen. The acids are then removed and recycled so there is no waste produced in the process.

The challenge is that the temperatures used are very high – approximately 1,000 degrees Celsius – and the acids themselves are very corrosive. Thus, the durability of the equipment used in this process is of great importance, and the researchers are studying what materials used to make the component parts hold up best during this process.

Interdisciplinary Collaboration

Many of the faculty members involved in hydrogen research on campus serve on more than one project, regularly consulting with one another and sharing insights. They also seem to share a philosophical commitment to producing an economical and environment-friendly fuel source.

“We are working together toward a common goal,” says Dr. Heske. “Solar, hydrogen, wind, bio mass, nuclear, and many other energy forms can all be part of an energy mix, provided that the research today achieves the breakthroughs required for a successful implementation of the new technologies of tomorrow.”

UNLV research in this field could have impacts well beyond the academic community, according to the dean of the College of Sciences.

“We are at the forefront of alternative fuel research efforts designed to solve our nation’s growing energy crisis,” Yasbin says. “The global economic, political, and environmental implications of this research cannot be underestimated, and I am proud that UNLV faculty are leading the way.”