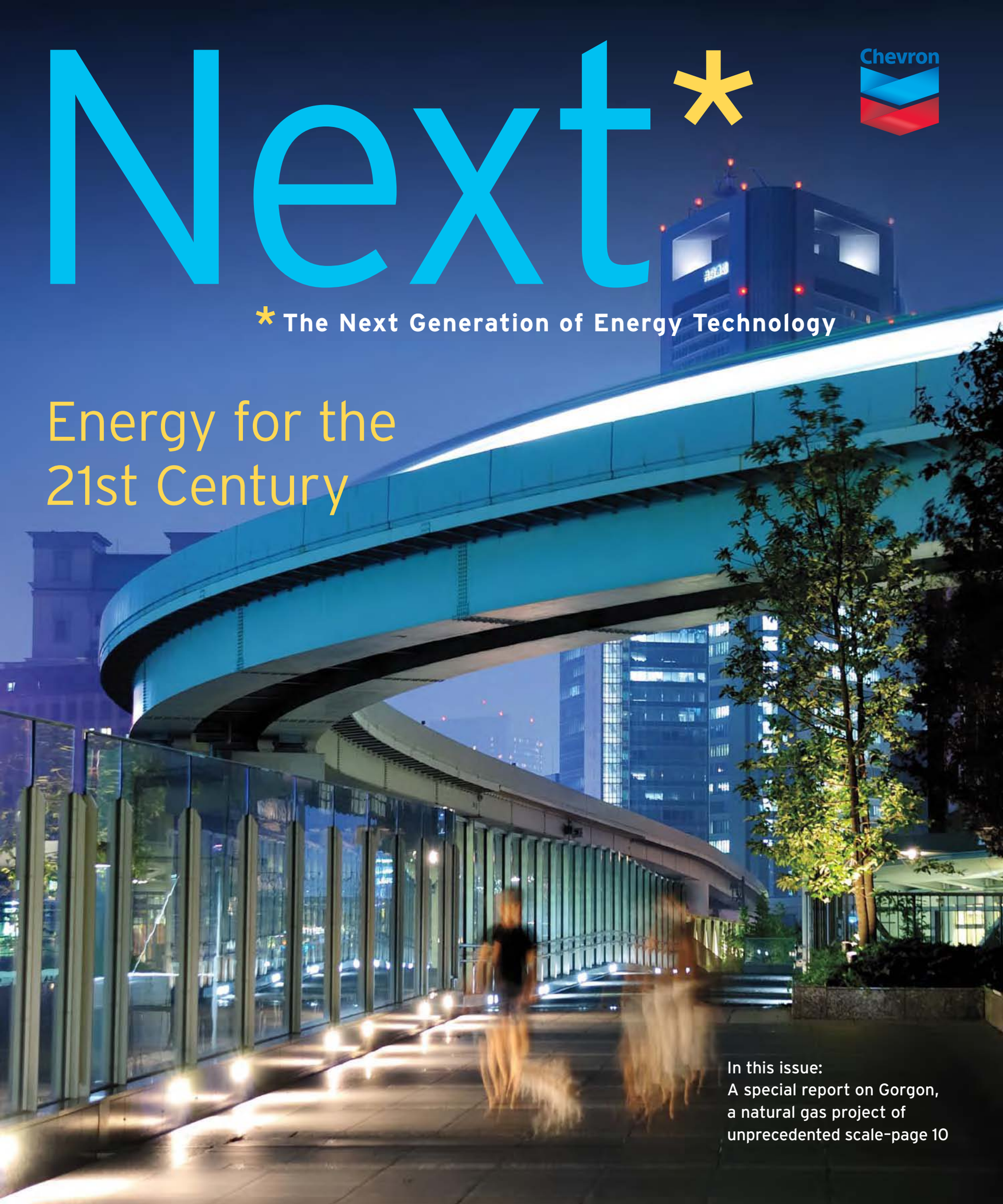
Next*

Chevron

* The Next Generation of Energy Technology

Energy for the 21st Century



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Location: Tokyo, Japan.

Japan is widely reported to be one of the most energy-efficient economies in the world. Chevron will supply Japan and other Asian countries with liquefied natural gas from projects in Western Australia.

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Next*
Issue 4, November 2010

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COVER PHOTO: VLADIMIR ZAKHAROV/GETTY IMAGES

Many Paths to the Future

Energy fuels human progress. Around the world, local economies depend on access to safe, reliable and affordable energy to meet basic human needs—light, heat, food, transportation—and to raise living standards. And the demand for this energy will continue to rise, as the world's population is expected to grow by about 20 percent over the next 20 years.

As a global society, how will we meet the aspirations and growing energy needs of developed and developing nations as populations increase, and how do we deliver this energy at the enormous scale required while minimizing impacts on the environment?

This is one of the great challenges of our time. The solutions depend not just on the choices made by business and government, but by people like you and me. And the solutions are enabled by technology.

Technology, and the know-how required to develop and deploy it at scale, will deliver the breakthroughs, just as they have done in the past. The world will need all the energy it can get from all sources, using technology to tap the high energy density, reliability and fungibility of hydrocarbons and to find ways of turning less dense feedstocks, such as biomass, into energy supplies at scale.

By necessity there will be many paths to the future, using different technology breakthroughs to get more energy from resources we already have—technologies that reduce carbon, enable resources of cleaner-burning natural gas or unlock renewable resources. To be sustainable, these solutions must be built on business models and technologies that are scalable, environmentally sound and economically viable.

This issue of *Next** probes such breakthroughs, including the development of a huge natural gas resource in Australia that has the world's largest commercial-scale carbon dioxide–injection project. It looks at new technologies that enhance oil recovery, shale gas production and reservoir management. These technologies can increase the ability to meet current demand while improving efficiency and reducing our environmental footprint.

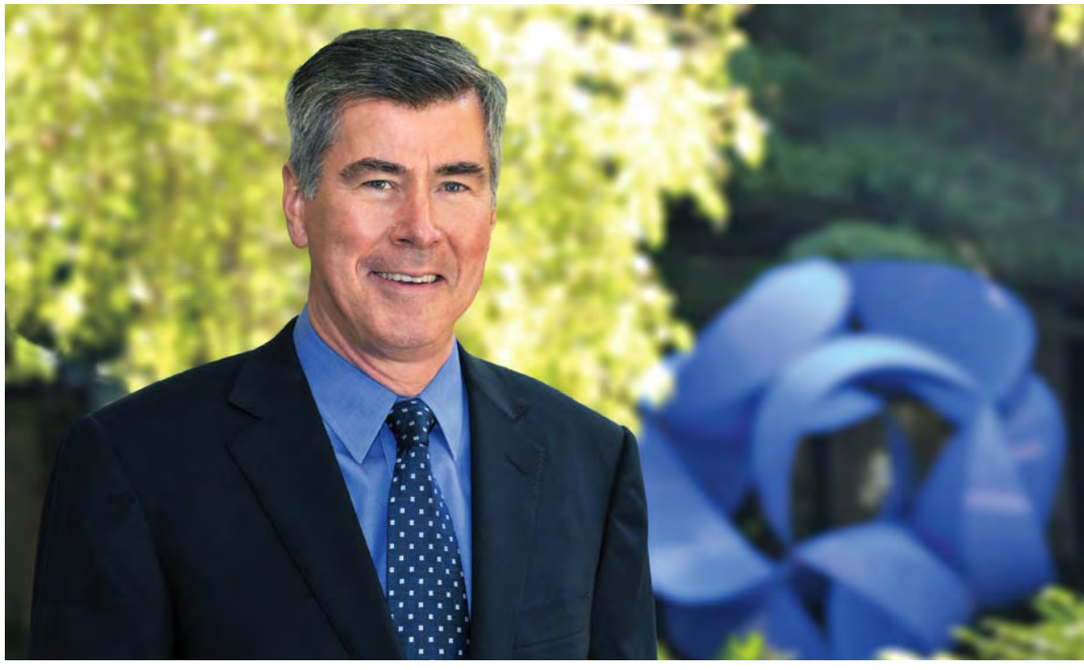


PHOTO: SUZIE SAKUMA

This issue also explores one university's work to develop our greatest and most plentiful source of new energy, the energy each of us can save through efficiency. Accessing this resource involves choices: the individual choices we all make each day—the cars we drive, appliances we use and lifestyles we adopt—and the choices businesses and institutions make to boost energy efficiency.

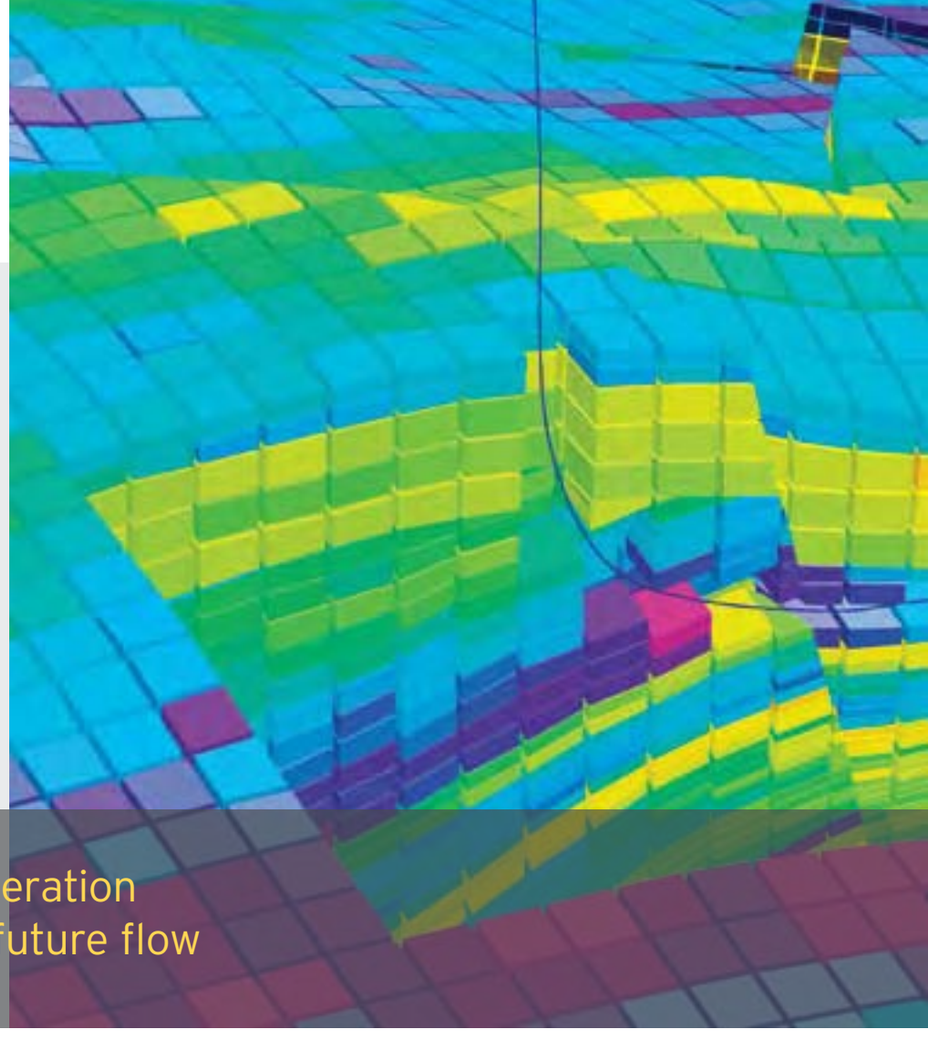
Technology is a great enabler. But even the greatest of enablers is ultimately just a tool. And tools rely on people, processes and, in a larger sense, collaboration in order to "get it right" on a safe and sustained basis. That's the value of partnership and an integrated approach to technology development and deployment.

Collaborating with government, academic and research institutions helps Chevron differentiate its performance through technology—by delivering superior performance in its core businesses and leading in emerging technologies, moving ideas off the lab bench onto pilot demonstrations and into large-scale commercial applications.

The challenges facing our world are immense, yet so are the opportunities for human ingenuity to create solutions. At Chevron, we call this human energy. As you'll see in this issue of *Next**, it's one form of energy in great abundance and is the catalyst for new technologies that facilitate human progress.

Sincerely,

John W. McDonald, Chevron Corporation
Vice President and Chief Technology Officer



Envisioning perfect oil fields, growing future energy streams

INTERSECT™: This speedy, next-generation reservoir simulator helps maximize future flow

Picture a mass of rock the size of Manhattan and the shape of a gigantic ice-cream sundae, two miles (3 km) underground, crisscrossed with cracks, and saturated with a high-pressure soup of dissolved minerals, hot water and raw petroleum—say, a billion barrels.

Next, build a computer model of this remote geologic wonder. Now, insert a virtual network of pipes, some to produce crude oil and natural gas, some to inject water, each placed perfectly among the jumbled layers and hidden pockets of energy. Start circulating the fluids and make the model move through the future like a living creature.

"Kind of like imagining blood flowing through bone marrow," said Paul Fjerstad, a petroleum engineer and simulation expert with Chevron Energy Technology Co.

Boosting world oil supplies

Congratulations. You have just constructed a reservoir simulation model. In this obscure game, earth scientists and engineers blend geology, geophysics, chemistry, mathematics, software and know-how to cram powerful computers full of data and make them reveal how to capture the most energy from oil and gas fields.

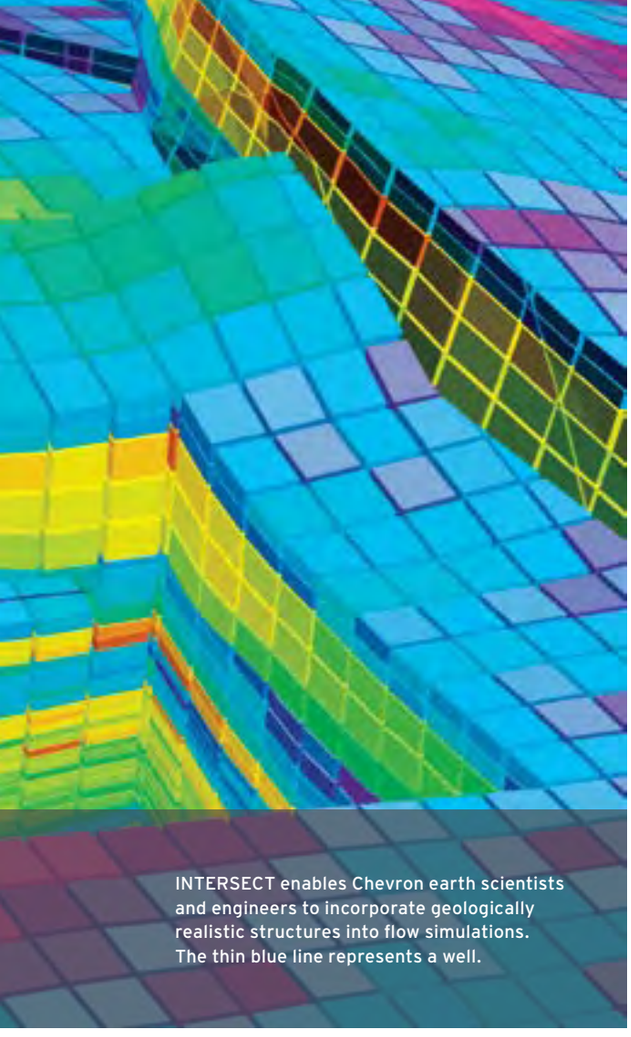
In Kazakhstan, Australia, China, the United States—and soon in many other countries—Chevron is stepping up to this critically important job with a powerful, next-generation simulator named INTERSECT™. Developed over 10 years under a continuing partnership with Schlumberger, a top international oil field services company, this speedy, new tool in association with other proprietary tools and techniques promises to help Chevron optimize productivity in new fields and make mature fields give up more of their resources.

"Once we can predict how much oil and gas we can capture, we can start designing ways to get more," said Fjerstad, who is managing Chevron's phased rollout of INTERSECT. "If we can predict 36 percent recovery, we should be able to improve our plan. We can put wells in more or better locations and recover 38 percent or 42 percent. Over the life of a billion-barrel field, the potential gains are enormous, and most of the world's oil fields have not been fully optimized with simulators."

Proving the potential

INTERSECT is steadily proving its potential, especially to support ongoing field management and planning for large, complex structures such as the giant, high-pressure Tengiz reservoir in Kazakhstan, site of Chevron's most extensive INTERSECT deployment so far. Greg King, a Tengiz reservoir engineer, said, "The simulator has improved run time of simulations and has delivered better results and better grid and well-bore physics. We've also reduced the time required to build the reservoir's actual behavior and production into our model, which greatly increases the accuracy of simulations."

GRAPHIC: CHEVRON ENERGY TECHNOLOGY CO.



INTERSECT enables Chevron earth scientists and engineers to incorporate geologically realistic structures into flow simulations. The thin blue line represents a well.

For the mammoth Gorgon natural gas development off the coast of Western Australia, INTERSECT sped up project planning and approval and enhanced production forecasting to help Chevron secure contracts for future output. And it is helping other operations better apply various recovery processes, including steam injection, to unlock heavy oil deposits, which hold great promise for supplementing the world's oil supplies, noted Viet Hoang, Ph.D., who specializes in adapting INTERSECT for Chevron's highly complex, thermal heavy oil projects in Indonesia, the Middle East, South America and the United States.

"INTERSECT gives us more realistic production scenarios that we can play with on a computer," said Fjerstad. "We can try different pressures, inject water, predict how much each well will produce—all very expensive to test in the field. And we can identify the best ways to improve or redevelop older fields and capture new oil missed by past development schemes."

The advantage of 'unstructured gridding'

INTERSECT depicts the personalities and moods of reservoirs in greater, sharper detail than did previous generations of simulators. The earlier technologies broke reservoirs down into three-dimensional configurations of rectangular-shaped building blocks. INTERSECT does this better—plus it elevates simulation wizardry to a new level with "unstructured gridding," crisply depicting faults and other difficult areas in the reservoir rock with curvy, individually shaped blocks.

The power of speed

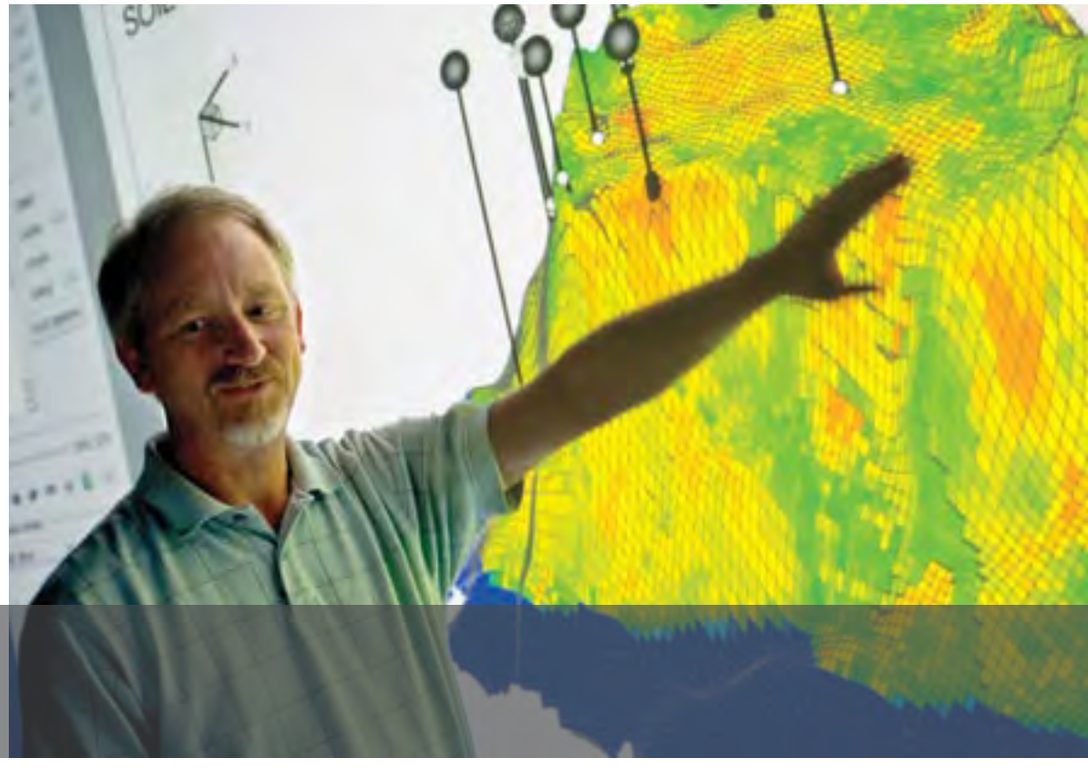
Perhaps most exciting, INTERSECT works its magic via parallel processing on high-performance computing clusters, dramatically increasing simulation speed. Significant uncertainty in the understanding of the subsurface requires testing a large number of scenarios to construct better development plans and field improvements, said Jitendra Kikani, program manager for INTERSECT at Chevron.

At Tengiz, simulations that once took eight days now take eight hours, Fjerstad added. For Gorgon, INTERSECT reduced to 10 minutes some tasks that once took six hours.

Putting INTERSECT to work

Chevron plans to steadily deploy INTERSECT throughout its business, focusing first on the top 20 largest, highest-potential fields and on areas such as the rich, heavily faulted reservoirs off the coast of Africa.

"I believe INTERSECT will give us a technical and competitive advantage and significantly strengthen our overall capability as an energy company," said Tim Magner, general manager of reservoir and production engineering. "I see it adding a great deal of value for decades to come." ■



Bill Milliken, a Chevron researcher in reservoir simulation, explains how the colors indicate oil saturation in the reservoir model. The black rods show the location of wells.

PHOTO: MAURA WARNECKE

Transforming Information Technology

Driving large-scale, fundamental changes to process, technology and culture

In remote Western Australia, a Chevron engineer quickly accesses an engineering contract from a database in the Singapore e-hub and reviews it with the design team in Houston, Texas. Meanwhile, a manager in the United States reviews her team's training needs with a simple click of the mouse. Across Kazakhstan, planning analysts for the Tengiz oil field seamlessly exchange ideas online about a new financial forecasting model.

At company operations throughout the world, employees are experiencing improved data access and productivity, as Chevron's information technology (IT) function transforms.

In 1997, Chevron implemented a global initiative to standardize desktop hardware and software. This indicated things to come, as Chevron has continually increased the speed and reliability of communications and improved collaboration capabilities. Now Chevron is moving to the next level and embarking on an IT transformation that will help the company more effectively leverage information and information technology, according to Willy George, general manager of the IT transformation program.

"Critical to a successful transformation is the mindset 'One Vision. One Journey. One Team,'" said George. "Organizations are working together and taking an enterprisewide approach to achieve what's best for Chevron." Given the scale and complexity of the IT operations that span Chevron's diverse businesses and locations, the transformation defined a long-term strategy with three-year targets:

- Prioritize IT investments to better align with Chevron's business strategy.
- Simplify the IT environment, with fewer data centers, applications and suppliers.
- Integrate global IT assets through consistent planning, control and standards.

"At the heart of each objective is the relationship between the line businesses and the IT function, which is changing from customer and service provider to great business partners," said Louie Ehrlich, Chevron's chief information officer.

Early successes

The transformation has already improved operations. Through a collaboration of IT members in Kazakhstan, the United Kingdom and the United States, Tengiz operations adopted a tool for network configuration that resulted in increased reliability and a simplified network environment.

Additionally, as part of Chevron's efforts to continually improve its environmental performance, six emissions reporting projects, including greenhouse gas reporting, collaborated across the corporation to develop one comprehensive report for government regulatory agencies.

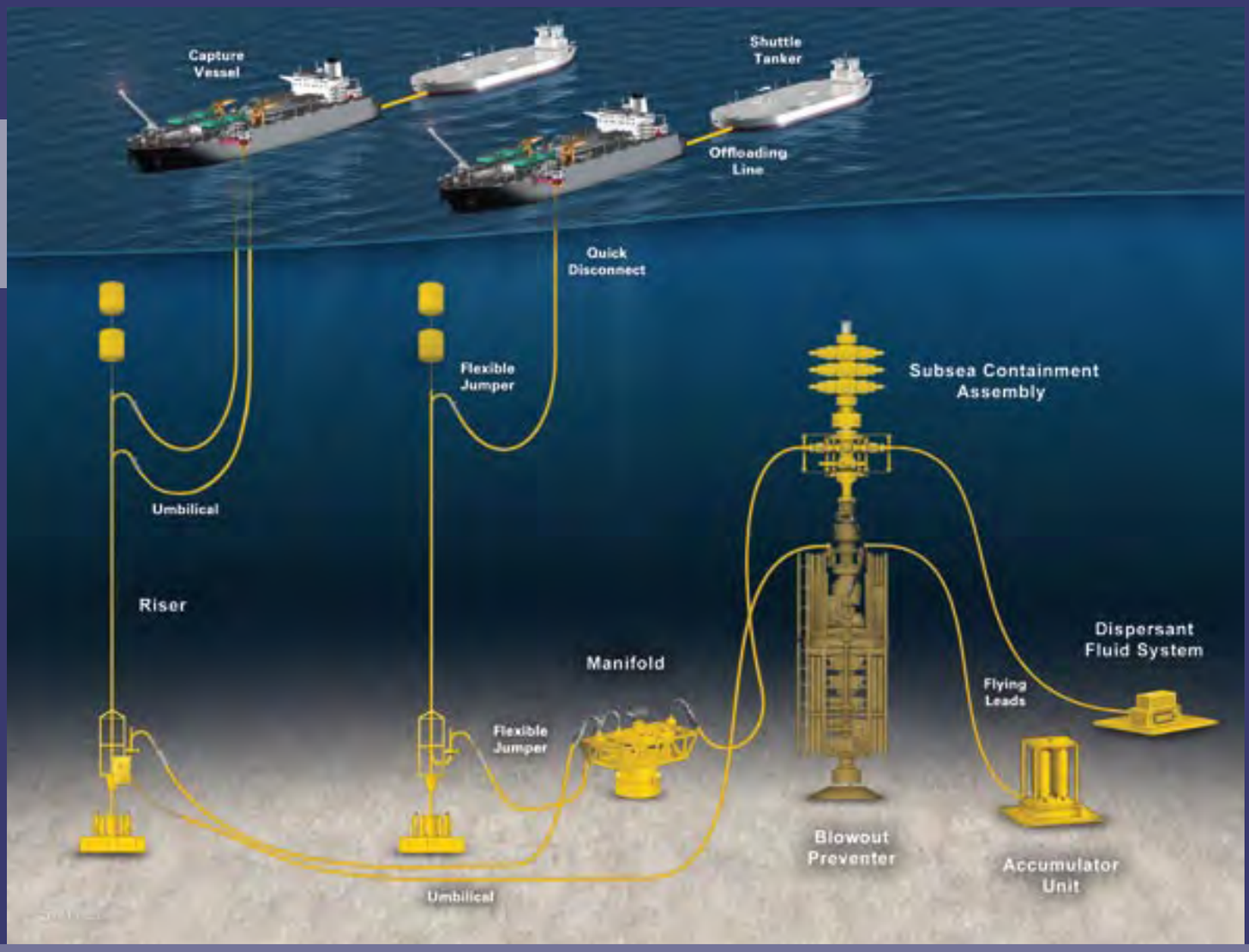
In another example, the joint efforts of the Australasia operations and IT teams in California and Texas identified an existing enterprisewide search solution that is expected to deliver robust technical capabilities now and in the future.

"In each of these successes, the underlying factor was that the business and IT tackled issues together," George said. ■

In just over a year, the information technology transformation delivered more than $100 million in value to Chevron.

PHOTO: MAURA WARNECKE

Willy George, general manager of the IT transformation program, is leading the way to prioritize, simplify and integrate.



Operational Readiness in the Deep

Chevron and partners plan a new well-containment system for deepwater operations

The BP Macondo well incident was a tragic event that deeply affects communities on the U.S. Gulf Coast. In light of this, Chevron is joining with ConocoPhillips, ExxonMobil and Shell to develop and deploy a new deepwater well-containment system. The four companies are committing $1 billion to design, build and maintain the new system.

Development of this new system will enhance deepwater safety and environmental protection in the gulf. Once constructed, system components will be maintained in a state of continuous operational readiness. Chevron's involvement in this initiative is part of an overall industry effort, which includes the formation of several multidisciplinary task forces, to improve prevention, intervention and oil spill recovery capability.

"We understand that we only operate with the public's confidence that the energy we need will be produced safely and reliably," said Melody Meyer, president of Chevron Energy Technology Co. "While we believe that spills are always preventable, this new system significantly enhances the industry's ability to effectively respond to any unforeseen incidents."

The planned new system's flexible and adaptable design will allow it to operate in deepwater depths up to 10,000 feet (3,048 m), in adverse weather conditions, and with flow rates exceeding the size and scope of any previously recorded spill. ■

ILLUSTRATION: COURTESY OF EXXONMOBIL CORP.

A Breakthrough in Fracturing

A new hydraulic fracturing fluid increases production without using water resources

Mike Langill, safety manager for GASFRAC, explains that all equipment is operated remotely using process logic controllers, remote observers, continuous gas monitors and closed-circuit television.

If the prediction continues to hold true and the era of easy energy is behind us, then technologies that increase the yield of new or existing crude oil and natural gas wells are of extraordinary value. A new fracturing fluid using liquefied petroleum gas (LPG) to improve the productivity of low-permeability reservoirs is one such technology.

Hydraulic fracturing is a technique used to create fissures, or fractures, that extend from the well bore into rock formations. These fractures allow oil and gas to travel more easily to the production well from the pores, where it is trapped.

At Chevron Energy Technology Co., engineers and scientists recognized the need for a significant improvement in fracturing technology. Wells often experienced long cleanup periods in tight gas sands in south Texas when using water-based fracturing fluids. A better fracturing fluid was needed; LPG ultimately became the natural choice.

"When fracturing oil or natural gas wells, water-based products are often the fluids of choice," said Tim Magner, general manager of reservoir and production engineering. "While water has been used for decades with much success, it has drawbacks for ultralow-permeability reservoirs.

PHOTO: JIM MACDONALD

PHOTOS: CENTER, ©2010 INACIO PIRES/SHUTTERSTOCK.COM; RIGHT, JIM MACDONALD

Vast resources of crude oil and natural gas lie trapped in reservoirs of low-permeability sand and shale, such as the rock at left.

To fracture today's tight formations, you need millions of gallons of water, which creates logistical and environmental obstacles. Additionally, water can damage the reservoir rock, resulting in decreasing yields."

Finding a substitute for water-based fracturing fluids was no easy task. The fluid needed to be nondamaging to tight rocks yet have sufficient viscosity to carry proppant—usually sand or a ceramic material—that props the fractures open. The fluid couldn't block the pores, or fractures, and had to be safe to use, for both workers and the environment.

LPG became a clear choice, and after several years of research, testing and patenting, Chevron commercialized the fluid. Chevron licensed the LPG fracturing fluid technology to GASFRAC Energy Services Inc., headquartered in Calgary, Alberta, Canada.

"GASFRAC Energy Services developed a pumping process that uses a closed, pressurized system," said Magner. "At moderate pressure and ambient temperature, the LPG—mostly propane—can be gelled and viscosified. This enables the LPG to carry proppant farther into the hydraulic fracture than water typically can, creating longer, effective fractures."

The LPG eventually vaporizes, mixing with the formation's natural gas and returning to the surface. "Gasification is crucial to the value of LPG," said Stacey Walker of Chevron Energy Technology Co. "Dollar for dollar, LPG is more expensive than water. But when it gasifies and flows back through the well, it saves the driller substantial cleanup and disposal costs. Additionally, the LPG can be recycled and used for other purposes or to liquefy and fracture another well.

"By using LPG, we are able to realize a higher yield of gas or oil," Walker continued, "and we don't take water away from other uses or have the demanding logistics of transporting millions of gallons of water to a well. We're friendlier to the environment, and the flow-back costs—the time and effort of recovering, filtering and reusing the fluid—are drastically reduced. It's exciting to use this technology and have a positive effect on our industry." ■

New oil supplies from the fourth dimension

Geophysical reservoir surveillance provides clues to tracking hidden oil and gas—and the benefits promise to be huge

Welcome to the fourth dimension, an underground frontier of time and space where Chevron's earth detectives are moving beyond their usual tough job of finding hidden energy resources to take on an even tougher job: tracking the migration of oil through giant rock reservoirs.

What's learned from this work, known as geophysical reservoir surveillance (GRS), has the potential to add billions of barrels of oil and trillions of cubic feet of natural gas to the world's energy reserves, said Larry Sydora, leader of the company's GRS team. Ultimately, GRS will help Chevron manage its assets as efficiently as possible.

The dimension of time

GRS employs several kinds of tools. But the most powerful is four dimensional, or time-lapse 4-D seismic surveying, based on the concept that two surveys are better than one. Said Bernard Regel, deepwater geologist with Chevron's U.S. Gulf of Mexico operations: "The more pieces of information we have, the more puzzles we can solve in the earth."

Three-dimensional seismic testing shoots shock waves into the earth's crust, then reads the bounced-back waves to reveal targets for exploratory drilling. But every discovered reservoir changes as resources flow out. Pressures drop. Groundwater moves. Layers settle. The acoustic properties of the rocks change, creating opportunities to gather new clues as production proceeds.

Comparing 3-D surveys of the same area a few years apart allows geophysicists to see these changes through time—seismic's fourth dimension—helping companies fine-tune their follow-up development work as fields are depleted.

"The technology is evolutionary, but the impact could be revolutionary," said Steve Smith, Chevron manager of deepwater producing assets in the Gulf of Mexico.

Enjoying hard problems

Looking out his office window in downtown Houston, Texas, Mike Allison, Chevron's head of reservoir management, applauds the contributions of GRS but also puts the situation in perspective.

"You want to be sure the technology will work as planned to generate new information you can act on," he said. "Better pictures of what's down there can produce potentially revolutionary results."

Try to imagine, he suggested, using seismic waves to map the floor plans, walls and ventilation systems within all the big buildings in the metropolitan skyline. What if something the size and shape of that skyline is buried 15,000 feet (4,572 m) underground beneath 3,000 feet (914 m) of ocean? Comparing your seismic survey to another from a few years back, could you map differences in air conditioning efficiency from one building to the next?

How to be precise, twice

Emerging over the past 20 years, GRS doesn't work everywhere because some reservoirs don't readily reveal their secrets with acoustics. For 4-D to work, surveys must try to hit precisely the same places twice—not easy in deep water. "Repeatability is the key thing in 4-D," said Regel.

As options mature, 4-D technology has already proved itself or shown great promise in fields operated by various companies in the Gulf of Mexico, Norway's North Sea, Brazil's Campos Basin and other areas. Chevron is planning global deployments of the technology.

"In my view, GRS has a very bright future, especially in Africa," said Pete Mitchell, geophysical team leader for the company's Southern Africa operations. He has high expectations for a planned 4-D survey of

PHOTO: ATLI MAR HAFSTEINSSON/NORDIC PHOTOS/GETTY IMAGES

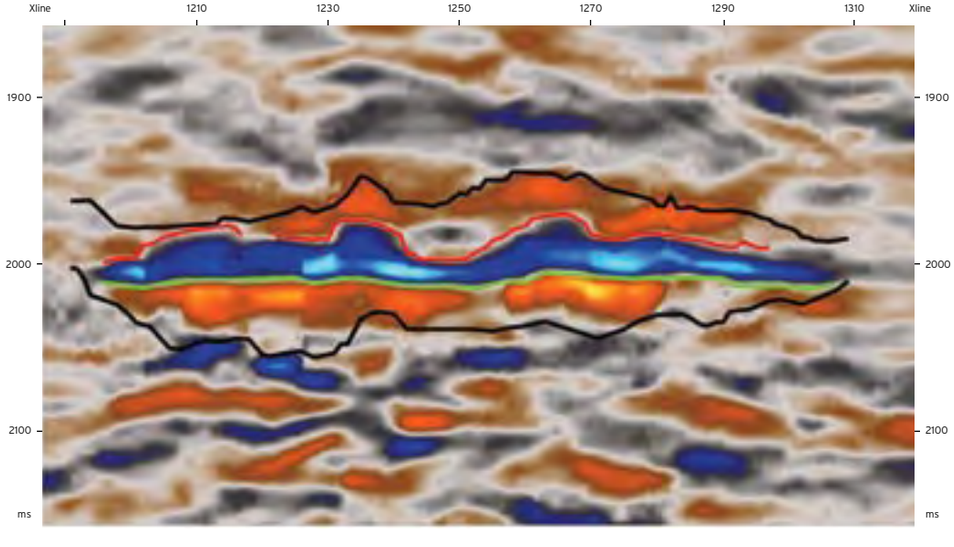
‘The technology is evolutionary, but the impact could be revolutionary.’

Chevron is planning to use GRS 4-D technology in the North Sea offshore Norway.

the oil fields operated by Chevron offshore Angola. “This will be our first 4-D survey, and we’ll compare the new data to a baseline survey from 2003.”

According to Regel, a 2006 seismic survey in one of the producing sands of the Gulf of Mexico’s Petronius Field reservoir, compared with an earlier survey, revealed a “baffle,” or rock obstruction, that had been stifling the ability of injected water to sweep oil toward the wells.

“The whole idea of GRS is trying to see where you’ve done a good job and where there may be bypassed oil or inefficient recovery,” said Smith. “It’s about precision and managing risk—we can’t make this work risk-free, but by better understanding the risks, we make better decisions.”



With 4-D seismic imaging, Chevron is able to track the movement of oil underground over time. In this segment, which shows approximately six years of acoustic impedance, black lines delineate the producing reservoir. The green and red areas, respectively, show contact of oil with water pre- and post-production.

GRAPHIC: CHEVRON ENERGY TECHNOLOGY CO.

Valuable in deep water

GRS is most powerful offshore and especially in deep water, where costs and logistics limit the number of wells in a field. Why? Wells directly provide many of the same kinds of information as GRS tools, such as well productivity, reservoir pressure, rock types and the ratio of oil to water.

Fields on land can often afford to have hundreds of wells. Offshore fields have a few dozen very costly wells, and in between are massive, mysterious expanses of jumbled rock where no wells provide production or clues. In the deepwater areas, where wells can cost $50 million or more, GRS can prove its value simply by confirming that a new well wasn’t needed because it likely wouldn’t produce much.

The next GRS hurdle: tallying and forecasting benefits against costs. “Quantifying the benefits is difficult,” said Regel, “but at the end of the day, we know we’re adding important new data and new oil. GRS is a very valuable tool, and it’s becoming a best practice.” ■

Explore how technology is intrinsic to Chevron’s operations at Chevron.com/Next/TechOverview.

UNCOVERING THE VAST RESO GO

A worker surveys the area around Barrow Island, the site of the Gorgon Project. For more than 45 years, Chevron has been operating safely on Barrow, showing that oil production and the environment can coexist.

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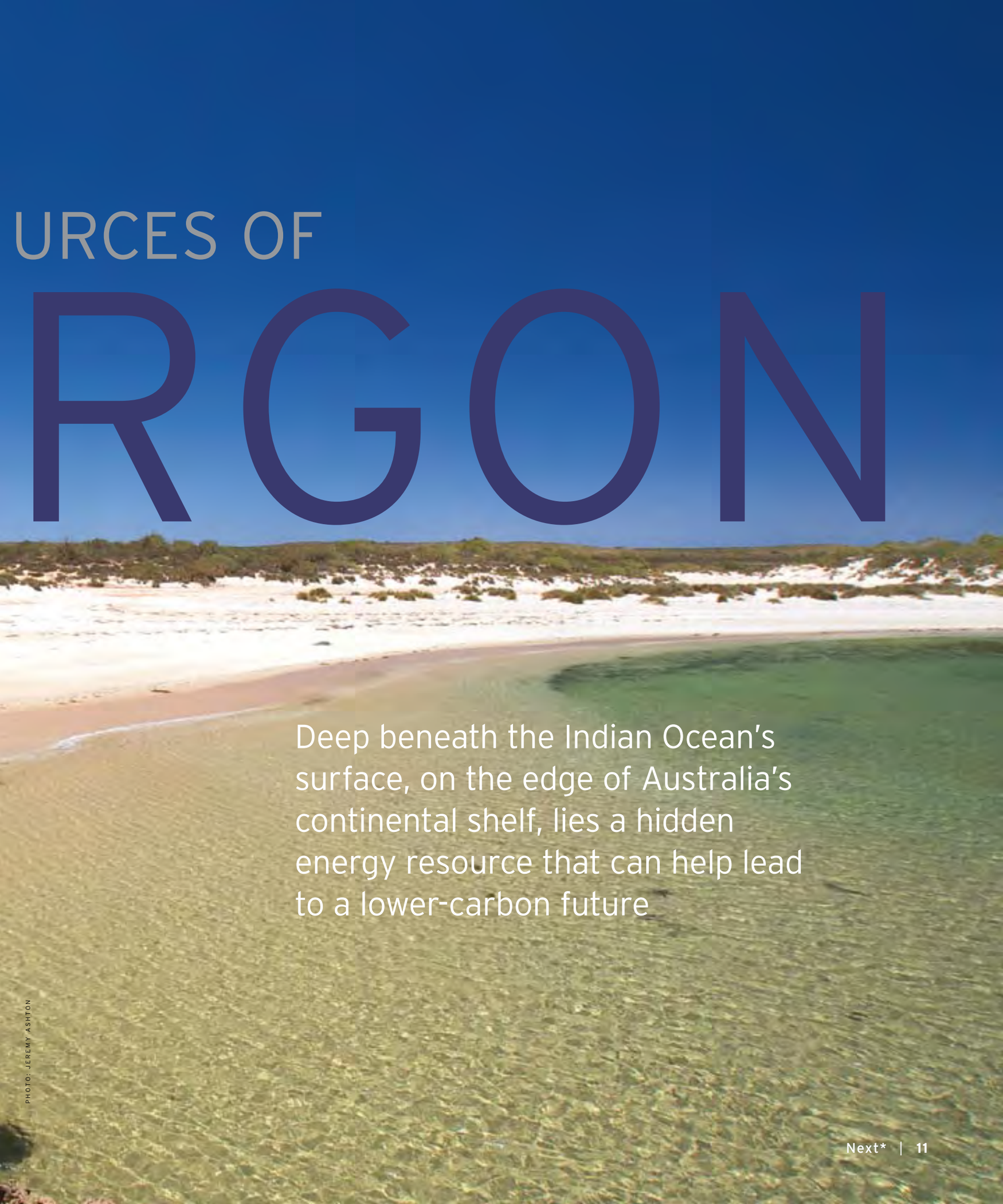


Deep beneath the Indian Ocean's surface, on the edge of Australia's continental shelf, lies a hidden energy resource that can help lead to a lower-carbon future

PHOTO: JEREMY ASHTON

Within the vast water wilderness, off the remote northwest coast of Western Australia, Chevron has discovered massive gas fields containing an estimated 40 trillion cubic feet of natural gas.

This is enough energy to power a city of 1 million people for 800 years, with cleaner, natural gas capable of meeting rapidly growing energy demands more efficiently and with less impact on the environment. The Chevron-operated Gorgon Project will harness this energy, becoming Australia's largest single resource project, incorporating its biggest subsea development and the world's largest commercial-scale project for carbon dioxide (CO_2) injection.

A project without equal

The complexity and scale of Gorgon are unprecedented—a long-term, technically challenging, complex energy development exemplifying a dramatic advancement of engineering know-how and environmental stewardship. And Gorgon will be among the world's most greenhouse gas–efficient liquefied natural gas (LNG) facilities.

The Karratha gas plant in Western Australia produces liquefied natural gas for the North West Shelf Venture, in which Chevron is a joint-venture participant. Liquefaction reduces the volume of gas approximately 600 times, making it more economical to transport between continents.

PHOTO: CHEVRON U.S.A. INC.

Barrow Island, 35 miles (56 km) off the northwest coast of Western Australia, will process natural gas from the Greater Gorgon Area gas fields.

The project plans include a 15 million-metric-ton-per-year LNG plant and a domestic gas plant to be constructed on Barrow Island, 43.5 miles (70 km) from the Greater Gorgon Area gas fields. LNG will be offloaded for transport primarily to markets in Asia, while domestic gas will be piped to the mainland.

Additionally, Gorgon will position Australia as a world leader in commercial-scale CO_2-injection technology. The company plans to safely inject and permanently store about 2 trillion cubic feet of CO_2 more than 8,200 feet (2,500 m) beneath Barrow's surface—four times more CO_2 than any previous project. This technology will help reduce the project's net greenhouse gases by 40 percent (see story on page 17).

The selection of Barrow Island as the preferred site for the development presents a unique situation for the project teams. The island was declared a Class A nature reserve in 1910, and its rare native fauna and flora have been sharing their home with Australia's largest onshore oil

(continued on page 15)

ILLUSTRATION: DAVID BERNHARDT/CHEVRON INFORMATION DESIGN AND COMMUNICATIONS

Barrow Island: Chevron's Track Record of Leaving Few Tracks

Barrow Island, a Class A nature reserve, has been home to Australia's largest onshore oil field for more than 45 years. Chevron's successful track record of operating on Barrow while protecting the environment helped the company gain the necessary permits to make the island the site for the Gorgon Project.

The project underwent a rigorous and thorough environmental assessment that culminated with some of the most stringent conditions imposed on a major project anywhere in the world. Thus, Chevron's management of the Gorgon Project raises the bar for environmentally responsible, large-scale technology deployment and innovation.

The island, renowned for its unique biodiversity and conservation value, was originally part of the Australian mainland before rising sea levels created a "living ark" for some native species that now exist only on this tiny patch of earth, protected from the introduction of nonindigenous plant and animal species.

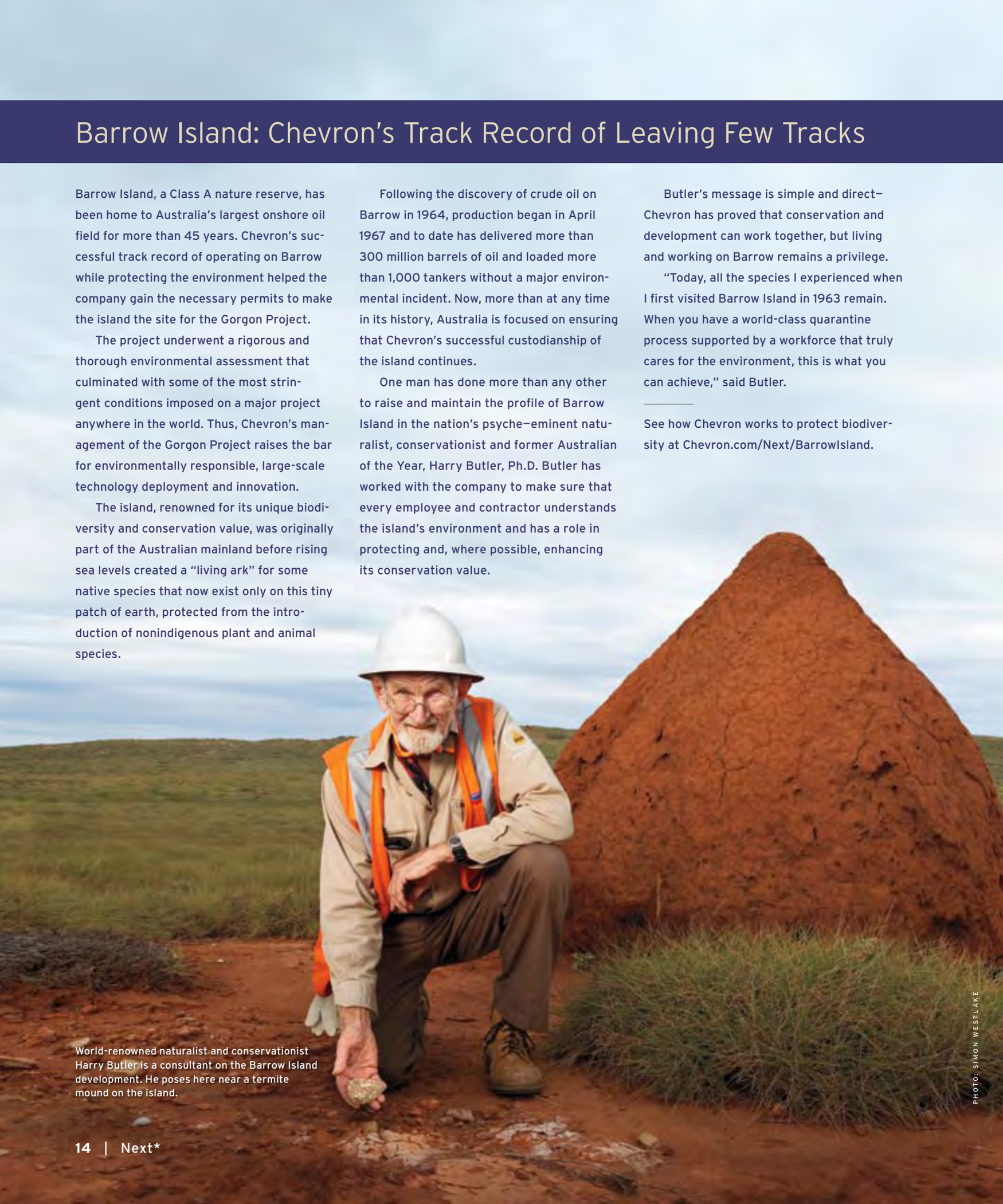
Following the discovery of crude oil on Barrow in 1964, production began in April 1967 and to date has delivered more than 300 million barrels of oil and loaded more than 1,000 tankers without a major environmental incident. Now, more than at any time in its history, Australia is focused on ensuring that Chevron's successful custodianship of the island continues.

One man has done more than any other to raise and maintain the profile of Barrow Island in the nation's psyche—eminent naturalist, conservationist and former Australian of the Year, Harry Butler, Ph.D. Butler has worked with the company to make sure that every employee and contractor understands the island's environment and has a role in protecting and, where possible, enhancing its conservation value.

Butler's message is simple and direct—Chevron has proved that conservation and development can work together, but living and working on Barrow remains a privilege.

"Today, all the species I experienced when I first visited Barrow Island in 1963 remain. When you have a world-class quarantine process supported by a workforce that truly cares for the environment, this is what you can achieve," said Butler.

See how Chevron works to protect biodiversity at Chevron.com/Next/BarrowIsland.



World-renowned naturalist and conservationist Harry Butler is a consultant on the Barrow Island development. He poses here near a termite mound on the island.

PHOTO: SIMON WESTLAKE

The Chevron-operated *Northwest Swan* is the newest and largest of the North West Shelf Venture's fleet. Unlike the other eight ships, which use spherical tanks, the *Northwest Swan* uses a membrane containment system. Chevron is a joint-venture participant in the North West Shelf Venture.

(continued from page 13)

field for more than 45 years. Chevron's custodianship of Barrow has been recognized internationally as a successful example of the coexistence of industry and the environment. Balancing the dual goals of development and conservation, the Gorgon Project will occupy just 741 acres (300 ha), or 1.3 percent, of the island's uncleared land mass (see opposite page).

Four thousand feet down

Gorgon's story of technological advancement and human innovation begins on the ocean floor.

Design of the subsea system, in depths of up to 4,265 feet (1,300 m), has intrigued some of Chevron's finest minds and is expanding the boundaries of the technology. The depth and terrain require technical innovations designed to make sure that the pipeline will withstand the formidable environment for the next 50 to 60 years. For example, Gorgon requires larger-diameter, thicker-walled pipelines engineered for higher pressures and corrosive fluids.

Between 20 and 30 producing wells will be drilled over 30 years. Subsea trees will connect to cluster manifolds via well jumpers, all on the ocean floor. Flow lines of various sizes, managed to guard against corrosion, will connect the pipeline termination structures together and form the conduit for produced fluids to the LNG plant on Barrow.

One major engineering hurdle was the need for the pipeline to traverse the continental shelf en route to Barrow, crossing an underwater escarpment 328 to 656 feet (100 to 200 m) high with slopes of up to 70 degrees.

A thorough analysis considered two routes: the southern route, with terrain that was more benign but added 28 miles (45 km) to the pipeline distance, would have resulted in increased

(continued on page 16)

PHOTO: CHRISTIAN SPROGOE

The Gorgon natural gas development on Barrow Island will occupy 741 acres (300 ha) of uncleared land, some of which will be just south of the Western Australia oil terminal tanks, above.

(continued from page 15)

back pressure and significant costs; the northern route, which was ultimately selected, saved installation costs and improved operability because of the shorter pipeline length.

Expanding the boundaries of technology

While the LNG facilities on Barrow Island will appear typical, the scale and complexity at this location will be unprecedented.

Con Kalimeris, a senior LNG process engineer with Chevron Energy Technology Co. (ETC) who works on Gorgon in Perth, Western Australia, explained, "One complication will be water in the well-stream fluids that are directed to shore. Water introduces the possibility of hydrate formation, which may lead to operating problems. We will inject monoethylene glycol (MEG) into the well-stream fluids to prevent hydrates from forming," said Kalimeris.

"While this won't be the first MEG system associated with an LNG plant, the size of the system and importance of preventing feed disruptions to the onshore plant require extensive design efforts and proper management during operation."

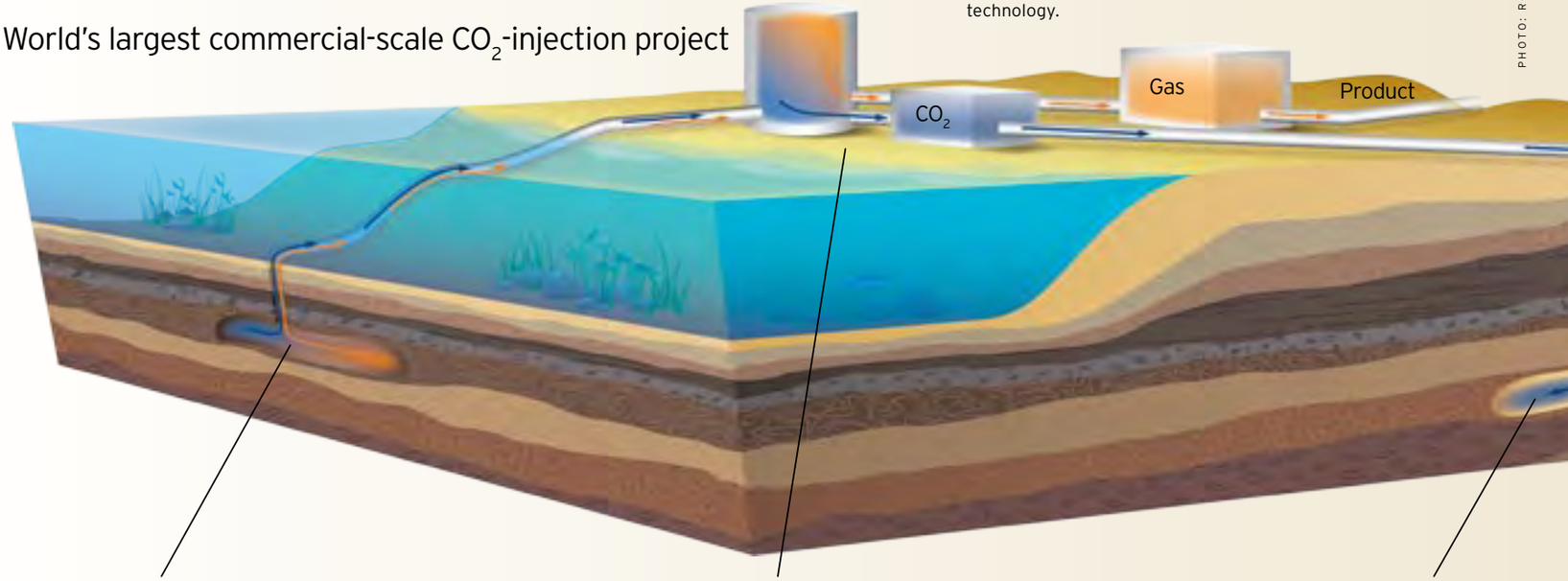
Additionally, to significantly reduce environmental impact to the island, many of the components will be prefabricated and assembled offsite into transportable parts. Other plants have been redesigned to enable modularization in expansion phases, but Gorgon is one of the only LNG projects in the world for which modularized construction was designed from the outset.

(continued on page 19)

Gorgon will position Australia as a world leader in commercial-scale carbon dioxide–injection technology.

PHOTO: ROBERT GARVEY

World's largest commercial-scale CO_2-injection project



1 Natural gas is fed from the reservoir to the plant.

2 CO_2 is separated from the natural gas.

3 CO_2 is compressed and injected more than 1.6 miles (2.5 km) underground into the Dupuy Formation beneath Barrow Island.

The World's Largest Commercial-Scale CO_2-Injection Project

As the search for new sources of natural gas pushes farther and deeper than ever before, extraction becomes more difficult and more complex. And the responsibility to protect the environment becomes more critical.

One of the most successful advancements in improving efficiencies and minimizing environmental impact is carbon sequestration, used to varying degrees on projects around the world.

Now, in a remote corner of Australia, as part of the Gorgon Project, Chevron is planning the largest project for carbon dioxide (CO_2) injection developed to date, four times the size of the largest existing operation. CO_2 injection is expected to reduce Gorgon's overall emissions by approximately 40 percent, or 3.4 million metric tons of CO_2 per year.

Raw gas from the Greater Gorgon Area fields contains up to 14 percent of CO_2, which must be separated before liquefaction. Depending on the final, ultimately recoverable volumes, the cumulative volume of reservoir CO_2 to be disposed of during the operating life of the project is expected to be about 2 trillion cubic feet.

The destination for this CO_2 is almost 8,200 feet (2,500 m) below the surface of Barrow Island, within the Dupuy Formation, a sand-rich reservoir with the properties required for a saline aquifer CO_2-injection project.

Donna Parker, Gorgon's CO_2-injection project manager, clearly understands the scale and complexity of the task ahead. "This will be the largest project of its kind and will position Chevron as a world leader in commercial-scale injection technology," she said. "We will be doing something never achieved before. It will be within a designated nature reserve; the technical robustness of this project has therefore been exhaustive, and our modeling of the reservoir has been long and iterative."

Gorgon will be capable of an average CO_2-injection rate of 220 million standard cubic feet per day via nine injection wells spread over three drill centers. The project also includes four water-production wells outside the expected CO_2 injection area in order to maintain reservoir pressure within accepted limits.

Mark Trupp, the project's subsurface team lead, explained that at this depth, CO_2 has a viscosity of a gas but a volume and density closer to a liquid.

"CO_2-injection rates are established by a complex interplay of factors," said Trupp, "starting with the maximum bottom-hole pressure required to avoid fracturing the formation." Injectivity, he explained, is also affected by the relative permeability of CO_2 in brine-filled rock, the thermal effects of injecting cooler CO_2 into hot rocks and the tendency of CO_2 to vaporize connate water—water that was trapped in the rock pores when the rock was formed—in the region near the well bore.

In addition to these factors is the mass-balance effect of injecting large volumes of a new substance into an aquifer. The pressure management system was designed to partially offset the pressure increase from injection. The hot formation water from the four water-production wells will be reinjected into a shallower aquifer, which will also minimize the environmental impact on Barrow Island.

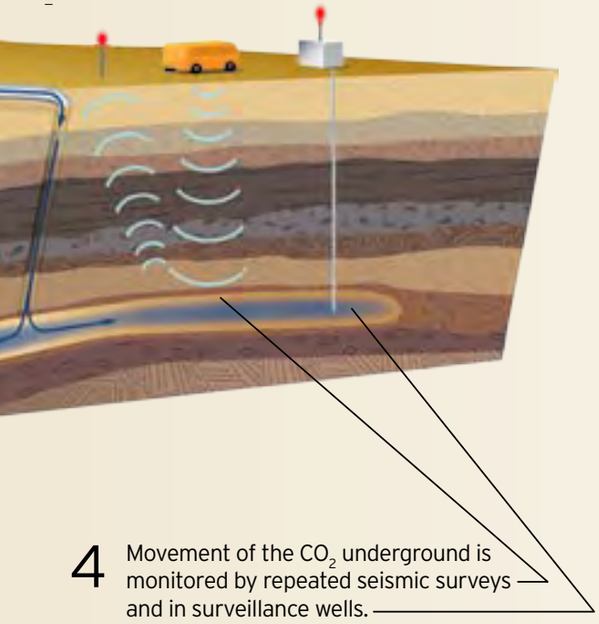
"The use of nine injection wells will help spread the CO_2 and result in lower concentrations within the injection interval," said Trupp. "This will help with long-term residual gas and CO_2 trapping. Seismic surveys, surveillance wells and surface-soil gas mapping will monitor and verify CO_2 movement."

Drilling is expected to start in 2012, with 17 wells in the initial project plans. LNG production of Greater Gorgon Area gas is expected to begin in 2014 with the startup of the Gorgon CO_2-injection project.

The Australian government has committed AU$60 million to the Gorgon CO_2-injection project as part of the Low Emissions Technology Demonstration Fund, which supports the commercialization of technologies that can reduce greenhouse gas emissions on a large scale.

Learn how Chevron is addressing climate change through carbon capture and storage at Chevron.com/Next/CO2.

ILLUSTRATION: AMY KWONG/CHEVRON INFORMATION DESIGN AND COMMUNICATIONS



4 Movement of the CO_2 underground is monitored by repeated seismic surveys and in surveillance wells.

Innovative Survey Techniques Minimize Chevron's Footprint

Acquiring baseline seismic data over the Gorgon CO_2-injection project area on Barrow Island presented a unique situation for Chevron's survey team.

Seismic surveys, which use sound waves and measure their echoes, are the most common industry method of acquiring data on the geological properties of rock strata below the land surface, in this case to monitor and safely store injected CO_2.

On Barrow, data were needed for a surface area of more than 33,360 acres (13,500 ha), which would normally result in the disturbance of 628 to 741 acres (250 to 300 ha) of land. Chevron, however, in keeping with its ongoing commitment to minimize the development footprint on Barrow, set itself a ground disturbance limit of just 62 acres (25 ha) and ultimately disturbed less than 47 acres (19 ha), just 0.01 percent of the total survey area.

Seismic surveys generally require clearing access tracks across the survey area, providing unencumbered access for vibroseis trucks and equipment. Vehicles are used over rough terrain to lay geophone array lines.

CO_2-injection project manager Donna Parker, Ph.D., explained that for this survey on Barrow, "The survey team approached tasks from a dual mindset—maximizing our conservation effort while not compromising our ability to achieve quality results."

To meet the geophysical, technical and environmental objectives, an innovative survey design using three different seismic energy source types were required. In areas of higher elevations, shallow porous limestone layers and varied terrain, seismic charges were placed into shot holes drilled to below sea level; whereas at lower elevations, a vibroseis source was used to better attenuate background field noise. In the shallow waters adjacent to Barrow, a low-energy airgun source array maximized seismic signals while minimizing potential impact on marine fauna.

"To minimize land transportation wherever possible during deployment," said Parker, "we used helicopters to transport drilling rigs and supporting equipment while crews carried lighter equipment by foot."

Shot points, vibroseis lines, offices and lay-down areas for equipment and cabling were placed where possible on existing cleared roads, tracks and land already earmarked for the Gorgon Project. Environmental and heritage surveys informed the placement of buffers around environmentally sensitive areas. To limit the access tracks, vibroseis trucks were reconstructed to reduce tire and axle widths. Stilts were used under support equipment, and hydraulic legs were constructed under drilling rigs to raise them above the vegetation.

Barrow Island's geology makes drilling difficult, particularly without the use of drilling fluids. Also, standard methods using mud pits were not chosen for the survey, given the land-use constraints and risks associated with heliportable operations. Instead, purpose-built air-percussion, or sonic, drilling rigs were designed to penetrate interbedded layers of fine sands and rock. The seismic team's safety commitment ultimately resulted in 15,000 safe heli-lifts over 927 helicopter hours.

"This extraordinary effort by everyone involved was vital to delivering baseline survey results and maintaining our reputation as an environmental champion of Barrow Island. We are all very proud of the achievement," said Parker.

Join employee Julia Baggs for an explanation of seismic technology at Chevron.com/Next/Seismic.

To reduce impact on the Barrow Island environment, a K-MAX helicopter transports seismic equipment during survey work for the CO_2-injection project.

PHOTO: TIMOTHY LOFTHOUSE

‘This collaboration has already resulted not only in the discovery of dozens of new species but also in unprecedented documentation of never-before-seen behaviors.’

(continued from page 16)

Bobby Martinez, technical team leader of LNG systems for ETC in Houston, added, “The project team has multiple yards working on different components to exacting design specifications. Every component must fit exactly to the framework so that there are no integrity issues. Then the completed modules must comply with intensive quarantine standards before reaching Barrow.

“Designing Gorgon has taught us many things, such as how to bend 60-inch (1.5-m) pipe and how high we can construct our plant without compromising operational integrity—valuable knowledge that we can apply to future sites,” continued Martinez.

Other aspects of the plant design relate to the unique environment within which it will operate, such as waste streams and water management. Modified lighting and ground flare use will minimize potential impact on nearby turtle-nesting areas.

“Every plant is different in terms of its location, but there is no doubt that Gorgon is on the cutting edge, not only in technology but also in the execution methods required to meet stringent environmental-approval conditions,” added Martinez.

A talented team

Chevron researchers, scientists and engineers throughout the world, led by people such as Bob Dimitroff, unit manager of ETC process engineering in Houston, have contributed to Gorgon’s design advancements.

“Building our LNG competency has been a long-term objective. In the early 2000s, we realized that the scale and complexity of planned future projects such as Gorgon would require an extensive suite of LNG engineers as well as experts in designing compressors, piping and other key plant components,” said Dimitroff. “We began by identifying the most experienced talent within Chevron and from our contractors, the wider industry, and the research and development sector. Once these competencies were established, we began attracting university graduates to help further build capability. The result is strong team competency within project locations such as Western Australia, from which we send people around the world to provide technical support at critical stages of development and execution.”

Gorgon also has benefited from the establishment of Chevron’s Asia-Pacific Global Technology Center in Perth in 2007. Center manager Paul Jones said, “We’ve got some of our biggest challenges here in Australia and great opportunities to differentiate our performance through technology. Our staff has the capabilities to face these challenges head-on.”

Jeff Buckles, ETC’s team leader for LNG development, agreed: “From modeling pipeline behavior to cutting-edge research in liquids separation and modularization techniques, Gorgon is giving us opportunities to apply our expertise and build our capability, capability we can transfer to other projects.” ■

For videos and animation on Chevron’s activities in Australia, please visit Chevron.com/Next/GorgonProject, Chevron.com/Next/LNG and Chevron.com/Next/PartnerAustralia.

PHOTO: CHEVRON AUSTRALIA

This deep-sea octopus was studied by scientists using Chevron’s remotely operated vehicles.

Uncovering New Worlds

Chevron and a group of Australian universities entered into a research agreement that will give marine scientists access to the company’s underwater robots to explore marine life at ocean depths rarely obtainable in the region.

Under the three-year agreement, research teams from the University of Western Australia, the University of Sydney, the University of Technology and the University of Wollongong will participate in SEA SERPENT, an international, voluntary collaborative of scientific institutions and oil and gas companies.

The program works by engaging remotely operated vehicles equipped with video and photographic equipment to study, photograph and collect samples of marine life.

The three-year project began yielding results after its first expedition in January this year, said Steve Vellacott, a Chevron environmental specialist. “It’s always remarkable that we find this type of animal life with relative ease despite there being limited food, water temperatures hovering between 41 and 50 degrees Fahrenheit (5° and 10° C), and depths of 1,300 feet (400 m) and beyond.

“This collaboration has already resulted not only in the discovery of dozens of new species but also in unprecedented documentation of never-before-seen behaviors.”

Please visit www.serpentproject.com.

In western Kazakhstan, Gulfara Mukhambetova is a lead safety specialist at the Tengiz Field, site of an industry-leading pilot project to reinject sour gas.

Enticing More From the Reservoir

Specialists in enhanced oil recovery improve production from maturing fields

PHOTO: JOHN SMALLWOOD

PHOTO: MICHAEL LEWIS

Too many in the oil and gas industry, a mature oil field with steadily declining production is a prime candidate for permanent shutdown.

But not at Chevron, where a group of engineers and scientists—such as vice president of Chevron Energy Technology Co., Chevron Fellow Ganesh Thakur, Ph.D.—is working to increase the yield of maturing assets. To Thakur and his colleagues, such a field offers an exciting opportunity to bring fresh thinking and new approaches to economically squeeze more production and reserves out of the ground.

Across Chevron's global activities, collaboration among company operations and partners has led to successful applications and leading-edge techniques to recover untapped reserves, significantly boosting volumes by 10 percent to 40 percent of their original oil in place. Moreover, Chevron's growing suite of enhanced oil recovery applications at complex and unconventional reservoirs is creating a competitive edge in attracting new business opportunities around the world.

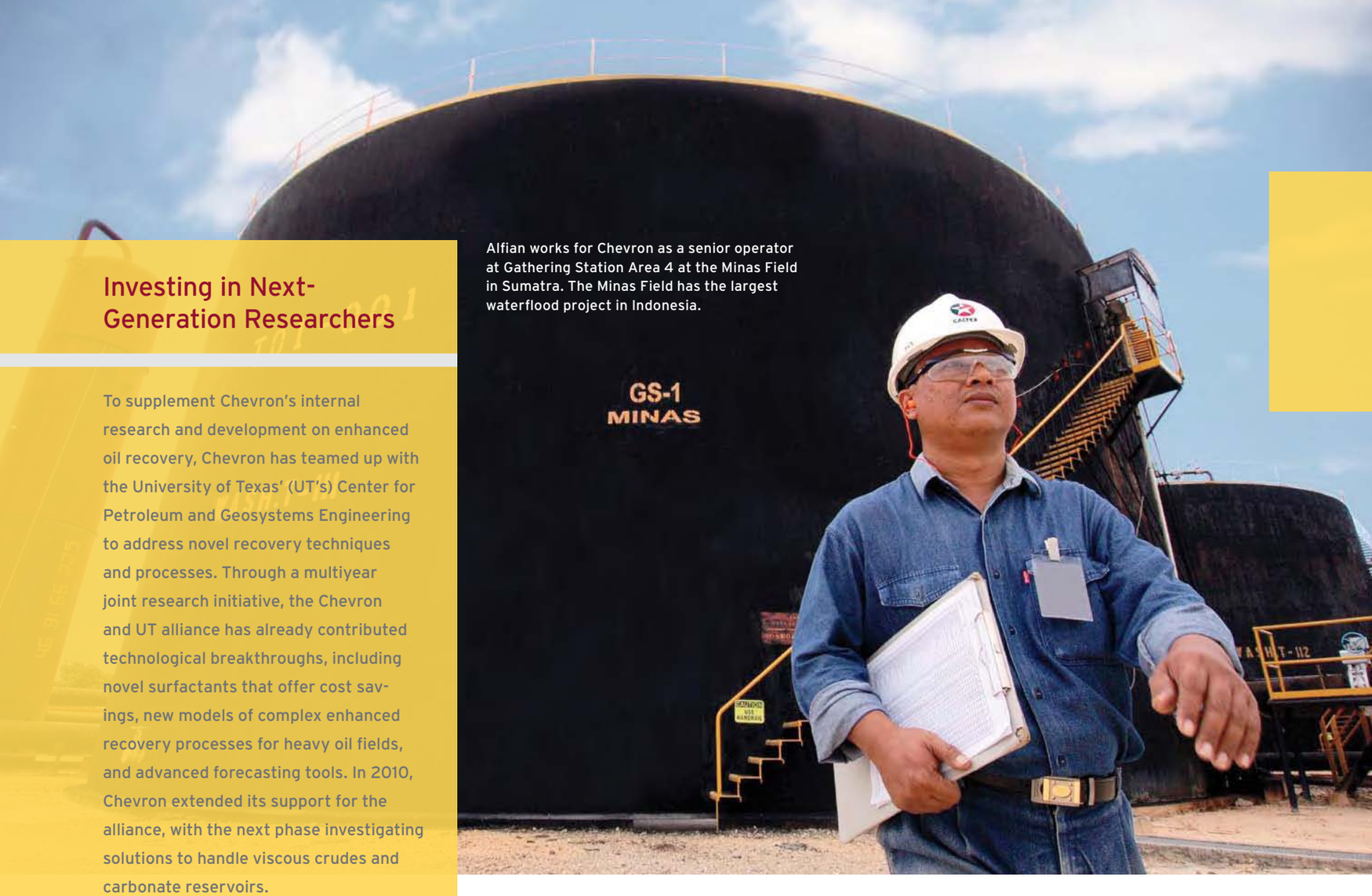
At most producing fields, primary and secondary recovery efforts—such as injecting water or natural gas into a reservoir—are sufficient to bolster production after output begins to fall. However, at difficult reservoirs—which include heavy oil, shale and sour gas—enhanced recovery techniques are necessary to tap into reserves that otherwise would be undeveloped. "Through advanced processes, we can increase recovery of hydrocarbons from a reservoir by up to three or more times what would be produced by conventional methods," said Thakur.

There is a wide range of enhanced oil recovery techniques, including thermal processes, such as steamflooding; nonthermal processes, which use gas, such as carbon dioxide, hydrogen sulfide, nitrogen and natural gas; and processes using chemicals, polymers and other products. All methods involve pumping gas, steam, chemicals or other specialty fluids into a reservoir to increase underground pressure and sweep hydrocarbons to a well bore.

For steamflooding, it's all about recovery. For shallow heavy oil reservoirs, primary methods may recover only about 10 percent of the original oil in place. With steamflooding, Chevron has been able to reach recovery rates of 50 percent to 80 percent.

"The type of application depends on the reservoir's geology and other factors. Chevron's specialists are well versed in unique characteristics of different recovery techniques," said Jack Stevenson, an area manager for heavy oil. "Although most oil companies use enhanced

Chevron and partners operate a steamflood pilot project in the Partitioned Zone between Kuwait and Saudi Arabia.



Alfian works for Chevron as a senior operator at Gathering Station Area 4 at the Minas Field in Sumatra. The Minas Field has the largest waterflood project in Indonesia.

Investing in Next-Generation Researchers

To supplement Chevron's internal research and development on enhanced oil recovery, Chevron has teamed up with the University of Texas' (UT's) Center for Petroleum and Geosystems Engineering to address novel recovery techniques and processes. Through a multiyear joint research initiative, the Chevron and UT alliance has already contributed technological breakthroughs, including novel surfactants that offer cost savings, new models of complex enhanced recovery processes for heavy oil fields, and advanced forecasting tools. In 2010, Chevron extended its support for the alliance, with the next phase investigating solutions to handle viscous crudes and carbonate reservoirs.

Along with bringing innovations, Chevron's investment in the UT alliance is helping prepare the next generation of enhanced recovery specialists. Chevron Fellow Ganesh Thakur noted, "Supporting the development of future researchers who will be directly engaged in addressing the world's energy needs is vital. And, for us at Chevron, it's personally rewarding to work with young researchers who share our passion for unlocking the potential of challenging reservoirs."

To learn more about enhanced recovery, please see the videos on California's Kern River Field, where steamflooding coaxes out hard-to-reach oil and benefits local agriculture at Chevron.com/Next/Steamflooding and Chevron.com/Next/EnergyAndOranges.

recovery applications, what sets Chevron apart is our extensive portfolio of practical knowledge and hands-on experience with a far-reaching range of techniques around the world. It takes both technology and technique."

A quick look at some of Chevron's enhanced oil recovery projects shows the breadth and scope of the company's technology leadership:

- **Kern River, United States** Since the introduction of steamflooding more than four decades ago, enhanced recovery techniques have already captured 67 percent of this 100-year-old heavy oil field's estimated 3 billion barrels of original oil in place. A pilot program to use horizontal steam-injection wells seeks to push ultimate recovery to 75 percent or higher at this field, one of the largest and most prolific in the United States, and this technology will have application throughout Chevron's portfolio.
- **Duri, Indonesia** Onshore Sumatra operations have applied steamflooding to about 80 percent of the Duri Field since 1985, ranking it among the world's largest steamflood developments. Chevron continues to expand recovery projects in Duri's northern section, which holds excellent potential for adding more reserves.
- **Partitioned Zone, Middle East** Leveraging Chevron's experience from the United States and Indonesia, the company and its partners operate a steamflood project at the Wafra Field in the Partitioned Zone between Kuwait and Saudi Arabia. The large-scale pilot project, which became operational in 2009, is expected to lead to full-field steamflooding in the First Eocene

PHOTO: PETER CANNON

> ‘What sets Chevron apart is our extensive portfolio of practical knowledge and hands-on experience. ... It takes both technology and technique.’

reservoir. If successful, it will be the first commercial steamflood in a carbonate reservoir in the world.

- **Permian Basin, United States** Nearly four decades ago, Chevron pioneered the injection of carbon dioxide (CO_2) into mature fields in the Permian Basin of West Texas and New Mexico, resulting in the world’s first commercial-scale CO_2-recovery operation. Chevron’s CO_2 projects have extended the productive life of these fields by up to 10 to 20 years. To advance its use of CO_2-recovery efforts, Chevron is conducting a pilot project at New Mexico’s Vacuum Field to apply CO_2-recovery methods in the high-water-saturation transition zone between the oil and water zones.
- **Minas, Indonesia** At the Minas Field in Sumatra, Chevron is advancing a pilot project that uses a chemical surfactant-polymer flooding process to recover additional reserves. The surfactant-polymer project represents Chevron’s ongoing efforts to economically capture more reserves and sustain production at Minas, where secondary recovery techniques have made this field the largest waterflood project in Southeast Asia.
- **Agbami, Nigeria** At the Agbami Field, Chevron’s vast experience in miscible gas and water injection is being deployed with a novel application of crestal gas injection and peripheral waterflood concurrently. This technique allows Chevron to maximize oil recovery and production by squeezing oil out of the reservoir with a “top down and bottom up” displacement mechanism.
- **Captain, U.K. North Sea** In an innovative approach to unlock this offshore field’s reserve potential, Chevron is testing enhanced oil recovery applications using polymers and chemicals to access resources not recovered during its initial development.
- **Tengiz, Kazakhstan** At Tengiz, the world’s deepest producing supergiant oil field, Chevron and its partners are making excellent progress with an industry-leading pilot project to safely reinject sour gas into reservoirs to yield higher production and boost recovery rates. Sour gas operations at Tengiz began in 2007, with full operations launched in mid-2008. These efforts along with plant expansions enabled Tengiz to double its overall production capacity.

Looking ahead, enhanced oil recovery will play an even greater role in bringing new energy supplies to the market as the industry focuses on developing complex and unconventional resources.

“Maximizing recovery from difficult reservoirs requires a commitment to research and development, a highly trained workforce, knowledge sharing, superior execution and world-wide operational experience,” Thakur said. “Our long history in managing a wide spectrum of enhanced oil recovery projects has placed Chevron at the forefront of this critical technology. Chevron affiliates are well positioned to help our global partners optimize the economic recovery of their oil and gas assets.” ■

Through enhanced recovery operations at the Captain Field, offshore Aberdeen, United Kingdom, plans are to increase estimated oil recovery from 34 percent to 50 percent and beyond.

PHOTO: JAMES GLOSSOP

Senior technology consultant Kevyn Renner poses with life-size replicas of the virtual avatars he and his colleagues inhabit when they enter virtual worlds.

THE VIRTUES OF Virtuality

Chevron is adding a new dimension to planning, training and collaboration through cutting-edge 3-D technology

The way humans learn and collaborate is enhanced by our environment. We quickly process and retain information through sensory experiences. We relate to one another and to situations based on the context of our environment, our shared knowledge and the application of our own specific acumen. Today, Chevron is leveraging technology to apply these realities of the human condition to training, planning and collaboration using 3-D environments that blend science and simulation to create a virtual world.

The Real Asset Virtualization Environment, a computer application developed by Chevron senior technology consultant Kevyn Renner, is believed to be the first of its kind in the industry. The application offers a 3-D virtual model of Chevron assets such as refineries, in which colleagues can work together using real-time information on real problems, training scenarios or future planning.

Choose an avatar

In the program, users are represented by avatars—3-D virtual replications of themselves—and can walk through virtual reconstructions of Chevron assets while collaborating with

PHOTOS: MAURA WARNECKE

Renner immerses himself in a virtual conference room while waiting for operations colleagues at the Salt Lake and Richmond refineries to enter. Renner recounts an experience in which trainees, when they were in the physical refinery, identified aspects that hadn't been discussed during the virtual training but that they had noticed on their own.

colleagues from around the world in real time. In this virtual world are note-taking tools, process documents and all the necessary resources for collaboration. If it sounds like something out of a video game, you're not far off.

"I saw how my kids became so immersed in gaming that they were in another world, and I knew educators were leveraging that in school and home-learning environments," said Renner. "I thought it would be interesting and useful to try and bring those same 3-D immersive advantages to Chevron. It has proved to be a powerful tool with almost limitless possibilities to help us work smarter, more safely and more effectively."

The journey from concept to reality, or virtual reality, required collaborating with operations throughout Chevron. They needed to buy in to this new technology and the real-world advantages it offered. After evangelizing his vision and allocating a budget, Renner and his partners built a proof-of-concept model—a precursor to the pilot—of the Salt Lake Refinery.

"Funding and building the system were just the initial hurdles," said Renner. "The level of computer savvy varies across the company. Some people are more used to manipulating avatars and exploring 3-D virtual environments. With others, their eyes sort of glaze over when you begin to talk about technology like this. So we had to find the right way of communicating our vision to those who would be using it and get them not only proficient in it but excited to use it."

Three test cases

The Salt Lake Refinery offered the perfect proving ground for Renner's program because a 3-D virtual model of its new hydrotreating unit already existed and could be imported into the new system with no additional design time or costs.

Three test cases were designed for the virtual environment. For operations and maintenance planning, Renner created a scenario in which a compressor wasn't operating properly; colleagues from different parts of the refinery had to collaborate on how to rearrange the plant while maintenance was conducted.

"Colleagues in specific roles look at a compressor differently in this situation," said Renner. "Our program allowed all of these people to interact in a virtual room, bringing their specific area of expertise and the ability to access all relevant documents."

PHOTOS: MAURA WARNECKE

Another test case was for hazardous-operations reviews. Specialists, who are often brought in for these reviews, now can remotely conduct them using 3-D virtual environments while the information is collected and saved for the U.S. Occupational Safety and Health Administration.

What about retention?

Perhaps the immediate use is in training. The virtual environment allows new operators who have never been in a refinery unit to learn in hands-on virtual environments by manipulating their avatars in a 3-D reconstruction of the refinery. The result is a safer training environment that can condense the training time needed to learn the same material in a classroom setting.

"It's very powerful," said Renner. "People are apprehensive at first, especially if they're completely unfamiliar with using avatars or gaming. But it's a pleasure to see them begin to get it, then enjoy it, then want to come back for more. We knew we were successful when people we had just trained on the system began suggesting additional test cases."

User surveys confirm what Renner was experiencing anecdotally: colleagues are responding to learning and working in 3-D virtual environments. Retention is higher and efficiency is greater. And practicing in a virtual environment before working in the real environment contributes to safety.

"We're taking a leadership position in adopting these innovative technologies and looking at applications throughout Chevron," said Renner. "The company has a lot of real assets that can be viewed in three dimensions and realized in a virtual world. This is just the beginning. We're still in the early stages of this technology. There's a lot more to come." ■

For a demonstration and tour, please visit Chevron.com/Next/DigitalRefining.

'I saw how my kids became so immersed in gaming that they were in another world, and I knew educators were leveraging that.'

The architect's 3-D drawing of the vacuum gas oil hydrotreater, seen below, already existed when virtual-training testing began, helping minimize development costs.

PHOTO: MAURA WARNECKE

Operators Tedi Kusyanto and Sutono walk along the cooling tower at the Darajat Unit III geothermal power plant in Garut, West Java, Indonesia. Darajat Unit III is Chevron's first project to earn carbon credits for reducing emissions.

The Darajat geothermal project is expected to reduce emissions by 650,000 tons of CO_2-equivalent per year.

PHOTO: TANTYO BANGUN

Investing in a Renewable Energy Future

Chevron is focusing on biofuels made from raw materials, such as high-biomass sorghum, that do not materially affect food or feed supplies.

PHOTO: NANCY DUNHAM

Chevron explores renewables as a viable enterprise

Where oil refineries once stood in California and Wyoming, Chevron has begun testing seven emerging photovoltaic solar technologies, and the company's first wind farm recently started churning out power for the local grid.

Meanwhile at a Mississippi tree farm, a forest-products company, under a research joint venture with Chevron, grows switchgrass to advance second-generation biofuels that use cellulose instead of corn or other food crops. And in Indonesia and the Philippines, Chevron taps boiling brine from deep in the earth to generate more than 1,250 megawatts of electricity for thousands of homes, making Chevron the world's largest geothermal power producer.

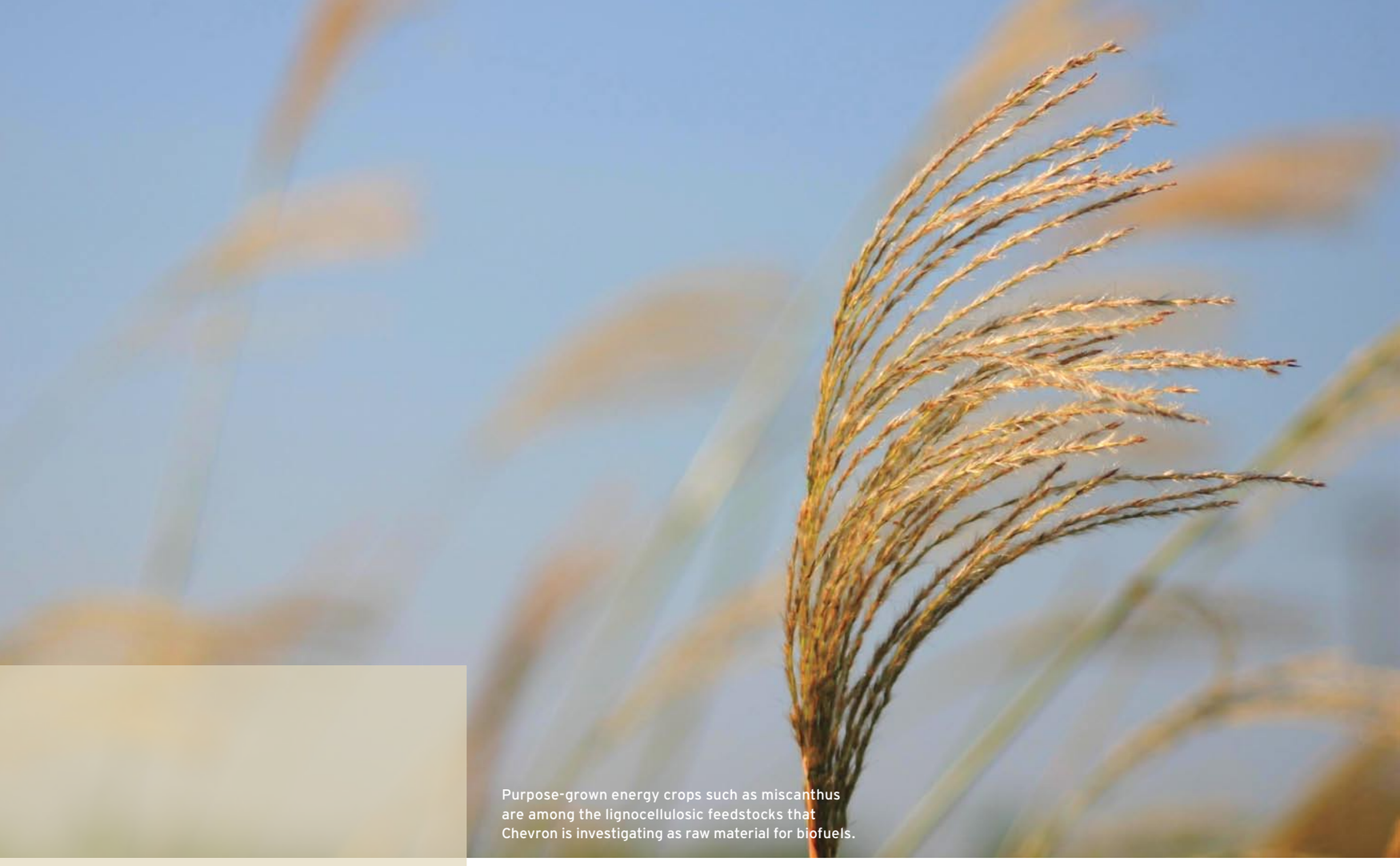
Promise and pragmatism

Renewable energy technologies such as these are hailed as sustainable alternatives, full of promise to provide clean, new energy and cut carbon emissions. But because of major technical hurdles—such as scalability, performance and costs—as well as market-based barriers, broader adoption can't happen overnight.

So Chevron pursues a strategy to promote energy efficiency while exploring renewables as a viable enterprise, according to John McDonald, Chevron vice president and chief technology officer.

World energy demand

"The world is going to need every molecule and electron of energy from all sources," said McDonald. "Our focus is on new sources that are feasible from a business standpoint, such



Purpose-grown energy crops such as miscanthus are among the lignocellulosic feedstocks that Chevron is investigating as raw material for biofuels.

‘The world is going to need every molecule and electron of energy from all sources.’

as geothermal power and energy efficiency. The key is to find and develop those technologies that show promise not just in the laboratory but in the commercial marketplace as well.”

Global demand for oil is approaching 88 million barrels per day, according to a recent International Energy Agency (IEA) report. Indeed, from 2007 to 2030, demand for energy of all kinds is forecast to increase nearly 40 percent, as reported in IEA’s 2009 World Energy Outlook. Fossil fuels will meet most of that new demand, but IEA forecasts that renewables can increase their contribution in the years ahead.

Chevron’s strategy

“Renewables can play an important role in the world’s future energy mix if we can unlock the secrets to providing them on a very large scale and at affordable prices,” said Des King, president of Chevron Technology Ventures, the company’s Center of Excellence for renewables strategy, research and development.

As part of its major business strategies, Chevron seeks to integrate renewable energy technologies into its business—including installing them at former operations sites—to improve its own operations, with a goal of reducing both costs and greenhouse gas emissions.

Chevron funds research and alliances with universities and government research facilities, including the U.S. Department of Energy’s National Renewable Energy Laboratory, to evaluate, test and apply these technologies. The company is actively involved in developing selected renewables—such as biofuels—that could complement its established capabilities in refining and fuel distribution.

PHOTO: NANCY DUNHAM

Additionally, through Chevron Technology Ventures, Chevron's venture capital arm, the company invests in emerging technologies and promising startups (see story on page 36).

"We make sound investments in research and testing in real-world applications to help solve tomorrow's energy challenges," said King.

Chevron is the world's largest producer of **geothermal energy**

Driving energy efficiency

Some technologies are ready now. Chevron Energy Solutions Co. (CES) is one of the United States' leading energy efficiency and renewable energy services companies and the nation's largest developer of solar installations for education facilities. CES develops and builds sustainable energy projects that increase energy efficiency and renewable power, reduce energy costs, and deliver reliable, high-quality energy. Consistent with Chevron's renewable energy and energy efficiency strategy, CES helps its customers, including Chevron, reduce their own energy use and find ways to put renewable power to work.

"Energy efficiency is the cheapest, cleanest and most plentiful source of 'new' energy we have," said Jim Davis, president of CES. Citing a McKinsey & Co. study, he noted that with a positive investment climate and a national commitment, the United States could reduce energy consumption up to 23 percent by 2020. "That would save about $1.2 trillion and reduce greenhouse gas emissions by an amount equal to that produced by all the nation's cars and trucks."

$1 billion in energy savings

CES has developed hundreds of projects that in aggregate are reducing customers' energy costs by nearly 30 percent on average, saving a total of more than $1 billion and reducing greenhouse gas emissions by more than 3 million metric tons since 2000. Customers include U.S. cities,

In the 1970s, two discoveries in the Philippines led to the development of the Makiling-Banahaw (shown) and Tiwi geothermal plants, which supply power to Luzon, the country's most populous island. Chevron innovations helped make the Philippines the second-largest geothermal energy–producing country in the world, after the United States.

PHOTO: ALEX BALUYOT

‘Renewables can play an important role in the world’s future energy mix if we can unlock the secrets to providing them on a very large scale and at affordable prices.’

A wind farm now sits on the site of a former Texaco refinery in Casper, Wyoming. The farm’s energy output of 16.5 megawatts, enough renewable energy to power approximately 4,400 homes, is sold to a local utility company for distribution to customers. Surveying the site are Chevron Global Power Co. employees Chris Buchholz, construction and operations manager, and Kara Cox, project engineer.

PHOTO: STEPHANIE WHITFIELD

counties, states and the federal government, school districts, community colleges, universities and correctional facilities.

Meanwhile, a corporatewide initiative has lowered Chevron's own energy consumption per unit of output by 31 percent since 1992, the baseline year. And the company has endowed the Chevron Chair in Energy Efficiency at the University of California, Davis, committing $2.5 million to help lead to the commercialization of new energy-saving technologies.

Integrating renewables

Pursuing beneficial reuse, Chevron this year started generating renewable power—enough for about 4,400 homes—with 11 wind turbines on a former oil refinery site near Casper, Wyoming.

At a similar site near Bakersfield, California, Chevron's Project Brightfield is testing seven emerging photovoltaic technologies to see which performs best. The results will help Chevron evaluate solar technologies for a variety of uses across the company. Power from the arrays will meet a small share of electricity needs at a Chevron oil field.

"This is one of the first projects to demonstrate solar technology on a reclaimed industrial site," said Jerry Lomax, Chevron Technology Ventures' vice president for emerging energy. "We hope what we learn here will be a bridge to a future with more renewables."

Meanwhile, at a Chevron Mining Co. reclamation project near Questa, New Mexico, the company is building a concentrating solar power installation. The largest of its kind in the United States, the 1-megawatt facility will use lenses that intensify strong alpine sunlight to feed high-efficiency photovoltaic cells.

"The demonstration will help us understand the benefits of this technology and determine its applicability in other Chevron operations and properties," said King.

Seeking biofuels synergies

The company is pursuing another promising renewable energy prospect: biofuels.

For decades, ethanol—an alcohol fuel made from corn and sugar cane—has been successfully blended into gasoline in large volumes in the United States, Brazil and other countries. But first-generation biofuels feedstocks often compete for food needed by humans and livestock.

Chevron's biofuels research alliances focus on new feedstocks—such as nonedible plant materials and algae—and on process technologies for converting this nonfood biomass into transportation fuels at commercial scale (see story on page 38).

From seed to scale

One example of a promising commercial partnership is Catchlight Energy LLC, Chevron's 50-50 joint venture with forest-products giant Weyerhaeuser Co. Catchlight is working to commercialize advanced biofuels made from forest-based biomass. Formed in 2008, Catchlight combines Weyerhaeuser's forest biomass expertise with Chevron's fuel processing and distribution capabilities to form a potential "from seed to scale" advanced biofuels supply chain. Biomass production could include intercropping—growing and harvesting biomass between tree rows in Weyerhaeuser's vast, managed forests.

"It's especially important to assess a variety of biomass sources because enormous quantities will be required to meet the potential demand for biofuels," said King. "And any new biomass initiatives need to incorporate the three major components of sustainability—environmental protection, economic feasibility and the minimization of social impact." ■

For links to information and videos on Chevron's activities in renewable technologies, please visit Chevron.com/Next/Geothermal and Chevron.com/Next/Biofuels.

Next*: ***What is Chevron Technology Ventures' (CTV's) role within the corporation?***

Des King: CTV is the "on ramp" into Chevron for emerging technologies. We act as a technology scout—looking for developments that can help our core businesses operate more competitively and in a more environmentally sustainable manner. That covers a broad spectrum—everything from new fuel sources to tools for managing information. Our objective is to identify and demonstrate emerging technologies that can benefit our operations.

Next*: ***How does CTV differ from other technology groups within Chevron?***

King: In a few ways. The first is the maturity of the technologies in our portfolio. CTV looks at early-stage technologies developed mostly outside of Chevron that have the potential to be deployed in the future.

The second is our commercial focus. CTV's expertise lies in the ability to evaluate the commercial potential of a technology and develop a business model around it. I like to say that we are not the people with the white lab coats, test tubes and beakers; rather, we are the people with the business calculators and spreadsheets who work with the technologists.

Next*: ***How do you access and demonstrate technologies?***

King: We use several avenues to bridge the gap between Chevron's technology needs and possible solutions that exist in the outside world. They include academia, government laboratories, entrepreneurs and early-stage companies. Our expertise in investigating and identifying possible technology providers is key to creating value. Of course, we also tap Chevron's internal expertise—for example, scientists in Chevron Energy Technology Co.—to aid us in our evaluation.

Next*: ***What happens once you identify a promising emerging technology?***

King: We develop a business model for it, often invest in it, and demonstrate it. After that, one of three things happens. One, we exit it because we find it's not a good fit. One example of that is our battery joint venture, Cobasys, which we decided to exit in 2009.

Two, we shelve it because it's not ready for widespread deployment and commercialization. An example of that is our hydrogen demonstration program. We successfully demonstrated hydrogen refueling technology at five U.S. locations over a period of several years and determined that it would have to overcome several hurdles before it could go any further.

Three, the technology proves successful at demonstration scale and we integrate it into our base businesses. At that point, that business would take it over and deploy it further, and we would move onto the next thing.

So, if CTV is doing its job correctly, its portfolio will turn over frequently and look different in three years than it does today.

Next*: ***Let's talk about a few technologies in CTV's current portfolio. What is the status of advanced biofuels?***

PHOTO: MAURA WARNECKE

Innovation Scouts
Bringing Emerging Technologies to Chevron

Desmond King, president of Chevron Technology Ventures, discusses the organization's unique role in Chevron's technology strategy and some of the promising emerging technologies in its current portfolio

King: CTV's goal is to evaluate all of the options and make recommendations by the end of 2012 as to how we can best fulfill our advanced biofuels obligations in the most profitable way possible. Since 2006, we've made a tremendous amount of progress evaluating many feedstocks and conversion technologies and have zeroed in on a handful of each. Now we are working with commercial partners to determine whether our preferred feedstock-conversion technology combinations can be scaled up economically to produce intermediates and finished products that qualify as advanced biofuels.

***Next*:** What are some other interesting areas in CTV's portfolio?*

King: CTV is demonstrating advanced solar technologies and how they could be integrated into our operations. In 2009, we began Project Brightfield, a demonstration of next-generation solar energy technologies in Bakersfield, California.

Project Brightfield is evaluating seven emerging, potentially low-cost photovoltaic technologies to help determine the potential application of renewable power at other company-owned facilities.

We are using a former Chevron refinery site to test these technologies side by side—six thin-film technologies and one crystalline-silicon photovoltaic technology, all by independent solar companies. The power produced during the testing phase will be directed to the local utility grid as well as used by our production operations at the Kern River Field.

Our Questa solar project in Questa, New Mexico, is another example of using existing assets to demonstrate renewable technologies. When completed in the fourth quarter of 2010, Questa will be one of the largest—if not the largest—installations of concentrating photovoltaic (CPV) solar technology in the United States.

CPV technology is more expensive but about twice as efficient as traditional solar power because the lenses used capture more available sunlight, then concentrate it and make it more powerful.

The Questa facility is being constructed on land that is part of an existing Chevron-owned mine, and it will supply carbon-free power to the equivalent of about 300 residents of Questa while we test the viability of CPV technology in a real-world application.

***Next*:** How do you see CTV's role in the future?*

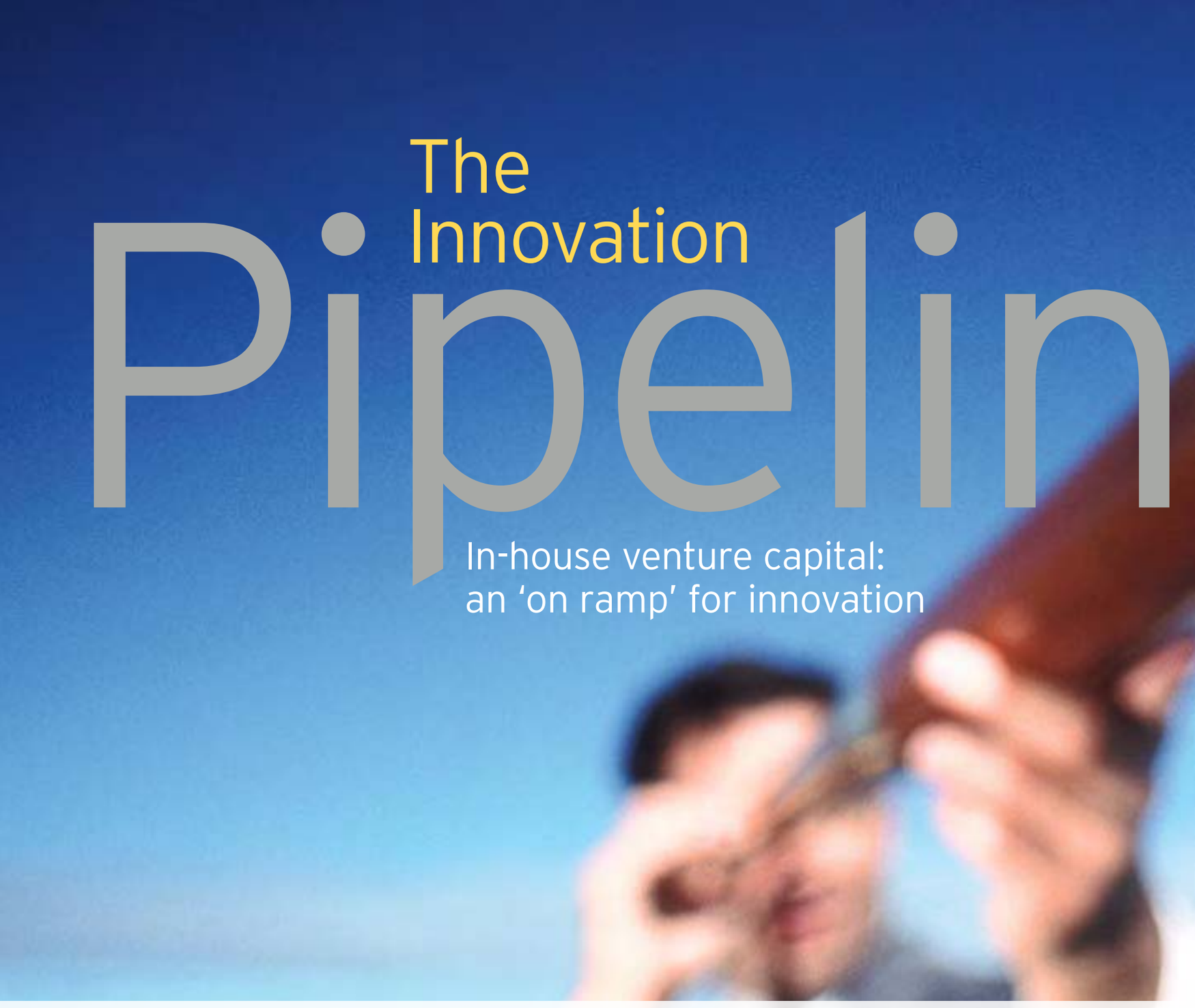
King: There will always be a need for new technology at Chevron. Competitive pressure and the necessity to be more efficient and more productive require that we be proactive in seeking new solutions.

In other words, we can't rely on today's technology indefinitely. CTV plays a critical role in helping bring the future to Chevron so that we can continue to deliver the energy the world needs and do it efficiently. I believe that will be as important 10, 20, 50 years from now as it is today. ■

PHOTO: HEMERA/THINKSTOCK

The Innovation Pipeline

In-house venture capital: an 'on ramp' for innovation



Fueling New Technologies and Entrepreneurs

For Chevron, the development of new energy technologies is an important focus.

The company's commitment to entrepreneurship, ingenuity and new technologies led it to become the inaugural global partner for the 2010 Cleantech Open. This one-of-a-kind annual business competition and mentorship program has enabled hundreds of clean-technology startups to bring their breakthrough ideas to fruition. In the process, it has helped alumni contestants raise more than $125 million while making thousands of green-collar jobs possible.

"We joined the Cleantech Open as a global partner based on the competition's outstanding track record of success," said John McDonald, Chevron vice president and chief technology officer.

McDonald added that "along with significant financial support, Chevron can offer something even more valuable—the knowledge and expertise we bring as a global energy company involved in every stage of the technology development cycle. We believe this is how the future of energy will be created—through great ideas, strong collaboration and business development."

Learn more about the competition at Chevron.com/Next/CleantechOpen.

The innovations below are diverse but have something in common:

- High-performance storage systems for computer data that facilitate faster and better business decisions.
- A revolutionary new process that can rapidly deposit diamondlike coatings on production tubing and other critical parts to protect them from harsh environments.
- Specialty chemical polymers that remove heavy metals and other soluble contaminants from water.
- Streaming real-time video sent from phones and other handheld devices to locations anywhere in the world.

The common thread is that each innovation was brought to Chevron by Chevron Technology Ventures (CTV). As the company's venture capital arm, CTV continually monitors emerging technologies, moving quickly to invest in commercial breakthroughs within the world's laboratories and early-stage companies.

Clear strategic value

"Our venture capital team provides a valuable innovation pipeline to new technologies that meet specific business needs in increasingly complex environments," said Des King, president of CTV.

Currently, CTV manages almost $200 million in strategic investments. Financial support can occur at any phase of the technology development cycle and may involve everything from seed investments to capital for full-scale commercialization. However, to be a viable candidate, a company must meet strict criteria, providing clear strategic value for Chevron as well as a superior financial rate of return. Current areas of investment interest include:

- New developments for the company's core crude oil and natural gas business.
- Emerging energy technologies such as biofuels and other renewables.
- Advanced materials, including atom-sized nanotechnology devices and micro-electro-mechanical systems.
- Wireless communications and advanced networking infrastructure.
- Information technology hardware and software innovations.

Once Chevron invests in a company, it works with that company to create a product or service best suited for adoption within Chevron.

Shoot for the triple win

Since 1999 when the program was first conceptualized, CTV has assessed approximately 3,500 early-stage companies—nearly one company per day for 10 years. It invested in 54 of them, resulting in 114 technology transfers. A technology transfer occurs when a Chevron business uses the technology. CTV aims for at least 10 such transfers a year.

"We shoot for a triple win with every investment we make," said Trond Unneland, vice president and managing executive of CTV. "The daring entrepreneurs whose work we champion receive Chevron's minority equity investment, become our suppliers and may grow to the point where they are acquired at an attractive price by another company. At the same time, investors who fund the emerging enterprise achieve an attractive return on their investment, and the Chevron operations that, as early adopters, embrace the new technology gain valuable operational advantages." ■

A video highlighting some of CTV's recent successes can be found at Chevron.com/Next/TechInvestment.

PHOTO: JOHN FOXX/STOCKBYTE/THINKSTOCK

Manager Michelle Long and her feedstock supply team at Chevron Technology Ventures helped Chevron quickly climb the biomass learning curve.

PHOTOS: PAUL S. HOWELL

Biofuels

Refining the Options

Advanced biofuels research is breaking botanical barriers

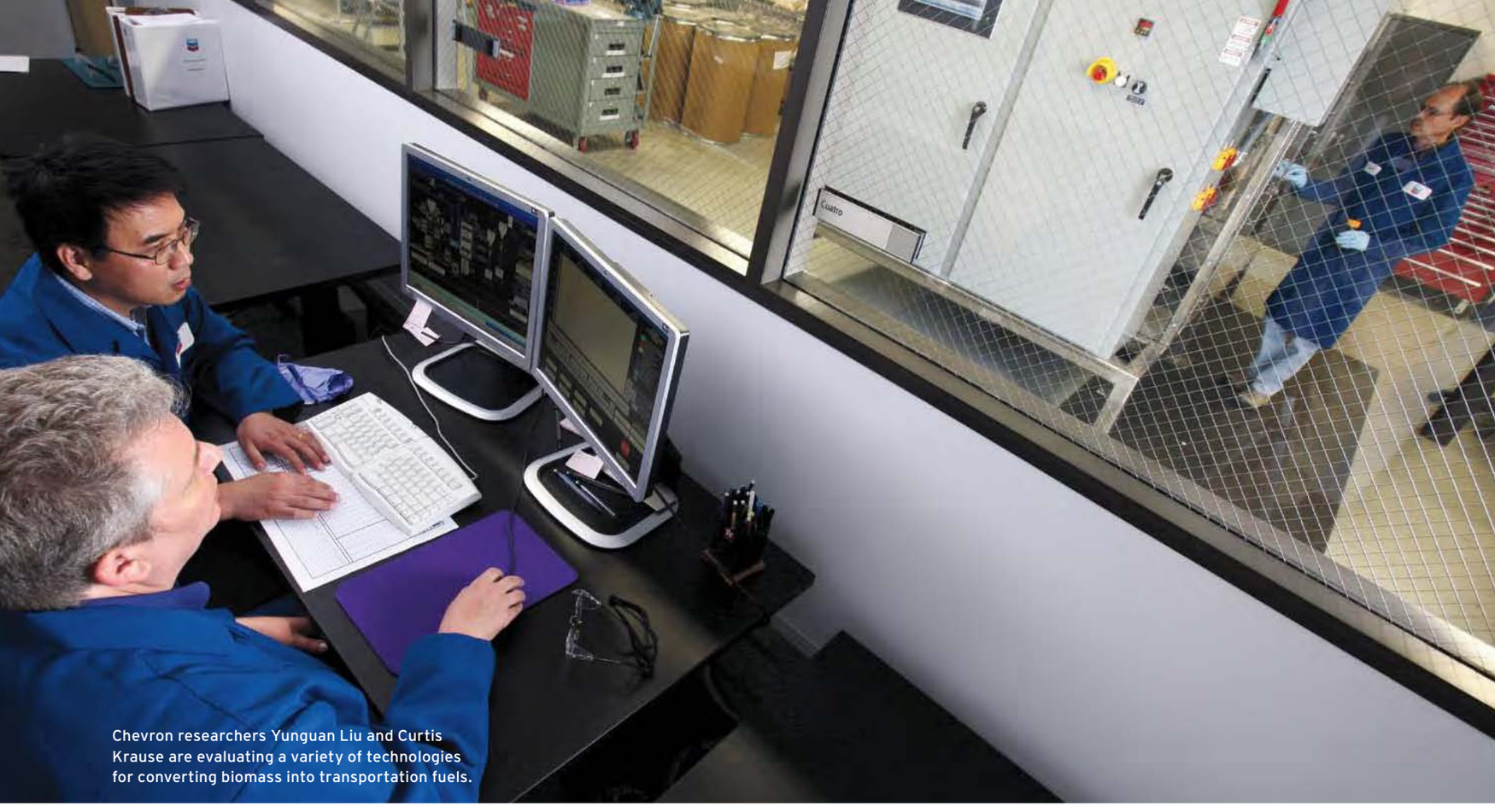
Michelle Long stopped in the middle of a central Texas jatropha field, leaned down, plucked a few pods off a plant and looked closely at them in her hand. "The fruit is too green. The seeds have not reached maturation for oil content," she said.

These days, Long, manager of feedstock supply for Chevron Technology Ventures' (CTV's) biofuels unit, is as comfortable examining jatropha seeds as she used to be exploring ways to efficiently manufacture products from long-chain hydrocarbons. But that wasn't always the case.

A quick glance at Long's background, education and professional career shows her to be an unlikely expert in germination, fermentation and a host of other terms straight from botany textbooks. A chemist by education and training, she has spent 15 of her 23 years in the industry in refining and lubricants operations.

Long's fast ascent up the biofuels learning curve mirrors Chevron's experience in feedstock research to date.

Scaling up conversion technology from the laboratory to the marketplace is a primary challenge for the future of advanced biofuels.



Chevron researchers Yunguan Liu and Curtis Krause are evaluating a variety of technologies for converting biomass into transportation fuels.

That education began in 2006 when CTV—the "on ramp" for emerging technologies coming into Chevron—was charged with launching and building Chevron's biofuels unit. Its task was to help Chevron plan and execute a biofuels strategy based on increasing volume mandates and the need to supplement traditional petroleum-based fuels to meet increased energy demands.

"Our first task was to find out what we knew and didn't know about biofuels," recalled Jeffrey Jacobs, CTV vice president for biofuels and hydrogen. He explained that there are three major components of biofuels development: feedstock, conversion and product.

"We knew a lot about conversion and product because we'd been using advanced engineering and manufacturing techniques to turn raw materials into high-quality transportation fuels for more than 100 years. But our knowledge about biomass—the raw materials for biofuels—was minimal. We had to get up the learning curve quickly."

'Focus on what we do best'

How does an oil company rapidly build organizational capability and institutional knowledge about biomass? One option—a very expensive one—would have been to staff up with botanists, agronomists and foresters and conduct all of its research in-house. But that's not always the way Chevron develops technology.

"Chevron's technology strategy calls on us to focus on what we do best and collaborate with the best and brightest in industry, national laboratories and universities to augment the areas where we need additional expertise," said Long. The research being done in cooperation with these groups includes a focus on biomass identification, characterization, cultivation and harvest.

Additionally, Chevron formed a 50-50 commercial joint venture, Catchlight Energy LLC, with Weyerhaeuser Co., one of the world's largest forest-products companies.

Mother Nature provides about

300,000

known plant species to evaluate for biofuels conversion

PHOTO: PAUL S. HOWELL

Using pond algae as the sole feedstock for advanced cellulosic biofuels would require a pond about the size of Lake Erie.

Thousands of possibilities

Before Long and her feedstock team could begin hands-on field trials of potential feedstocks, they first had to tackle the not-so-small problem of the sheer number of choices.

Mother Nature provides plenty of options: about 300,000 known plant species plus a huge number of potential nonplant feedstocks such as algae, animal products and waste streams. It was difficult to know where to start.

"Our goal was to zero in on the handful of feedstocks with the greatest potential to produce biomass at scale and in an environmentally and economically sustainable manner," explained Long. "In 2007, we evaluated 110 potential feedstocks and eliminated all but 24."

Long's team then applied more rigorous selection criteria to those 24 feedstocks. The four major criteria for passing this phase were volume potential, risk assessment, feedstock characteristics and delivered economics.

Lignocelluloses and lipids

By the end of 2008, CTV had prioritized 11 feedstocks in two broad categories—lignocelluloses and lipids. Included in the first category are forest residues, agricultural residues and purpose-grown energy crops such as switchgrass and miscanthus. Examples of lipid-based feedstocks include algae and oil seeds such as jatropha. Some of these feedstocks are the focus of CTV's internal R&D, while others are the focus of Catchlight.

CTV is now learning where feedstocks grow most effectively in large quantities and how to harvest and transport them cost effectively. It is particularly interested in those that thrive on marginal land that food or feed crops wouldn't use.

"We've come a long way in four years," said Jacobs. "From an almost infinite number of feedstock-to-product pathways, we are now able to concentrate on fewer than 10 that we believe can give Chevron a competitive advantage." ■

PHOTOS: PAUL S. HOWELL

What Needs to Happen

Chevron believes that advanced biofuels are a natural extension of the company's core competencies and that they will play an increasingly important role. But significant difficulties stand in the way.

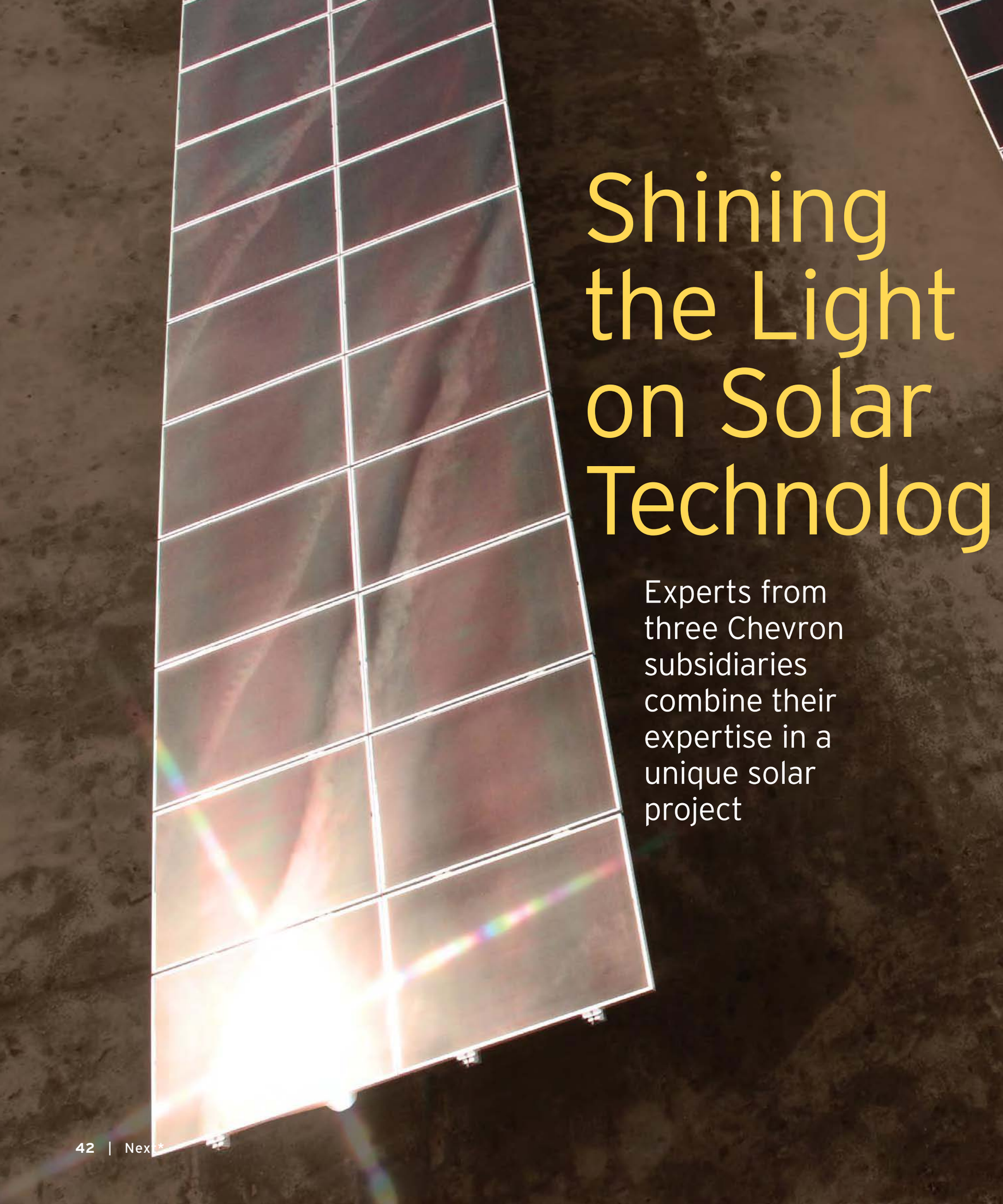
"Perhaps the most important outcome of our research is the realization of the enormous complexity facing commercialization," explained Des King, president of Chevron Technology Ventures. "The industry must continuously produce massive amounts of biomass and build hundreds of biomass conversion facilities. Many companies are focused solely on developing conversion technology, but it's those who have stepped back to look at the whole 'seeds to wheels' concept who appreciate the magnitude of the scale issue."

Consider the following: The U.S. Renewable Fuel Standard calls for advanced cellulosic biofuels for blending into transport fuel to be ramped up from virtually zero today to 16 billion gallons (60.6 billion liters) per year by 2022. Hybrid poplar trees as the sole feedstock for that amount of fuel would require growing and managing a forest about the size of New Mexico and harvesting yearly a portion of it about the size of New Jersey. Using pond algae as the sole feedstock would require a pond about the size of Lake Erie, harvested continually throughout the year.

"Those are sobering numbers," said King, "and they demonstrate why multiple feedstocks—and multiple conversion technologies—will be required to meet advanced biofuels obligations.

"We are working diligently on the advanced biofuels puzzle," explained King. "But society must be realistic about the difficulties and the time needed for technical and scientific breakthroughs. As our scientists are fond of reminding us, 'You can't schedule innovation.' "

Learn more about emerging fuel technologies at Chevron.com/Next/Biofuels.



Shining the Light on Solar Technolog

Experts from three Chevron subsidiaries combine their expertise in a unique solar project

ies

Experts from different businesses within Chevron have been collaborating on Project Brightfield. Here, hydrogeologist Leslie Klinchuch (left) and former president of Chevron Environmental Management Co. Janeen Judah inspect the installation of solar panels.

PHOTOS: DON STACY

Chevron looks for ways to meet the increasing demand for energy not only on a global scale but also on a regional scale, considering the energy resources available and the viability of specific technologies. Chevron's Project Brightfield is a prime example. Located on a former refinery site in southern California, this unique renewable power installation is demonstrating a valuable new use for the land while testing the potential of promising solar technologies.

The power of three

A collaborative team of three Chevron companies—Chevron Technology Ventures, Chevron Environmental Management Co. and Chevron Energy Solutions Co.—looked at how it could make best use of some of Chevron's existing assets. The team realized that former refinery sites or other repurposed lands might be suitable locations for renewable facilities.

One of the biggest hurdles for integrating renewable technologies is finding an area large enough for a mid- to large-scale facility. The team identified four California sites that provided enough land mass and were conducive to solar energy production. They selected a former refinery site in Bakersfield, California, close to Chevron's Kern River Field and near the local power grid.

"When we looked at the land mass available, we recognized an opportunity to explore a renewable technology in a way that hadn't been done in our industry," said Chevron Technology Ventures project manager Adam Williams.

Seven of the best

The team combined its expertise to design, build and operate a comprehensive research and demonstration facility. With the phenomenal growth and competition in the solar industry over the past five years, the team had to find the best technologies and viable suppliers. It narrowed its selection to seven promising, next-generation technologies from among hundreds.

The five-year demonstration project covers about 8 acres (3 ha), includes 7,700 solar panels and produces about 740 kilowatts of energy that may be used to augment nearby Chevron oil production operations or be integrated into the local power grid. The facility includes a station that monitors sun radiance, temperature, rain, wind and humidity to correlate technology performance with weather. Each provider can access data about its solar technology, find out how well it performs in various conditions and compare it against an industry benchmark.

Based on the demonstration, Chevron will determine whether it makes sense to integrate these technologies at other facilities and, if so, which technologies might prove more viable.

"This facility allows us to make decisions about renewable technologies based on what we're seeing firsthand," said hydrogeologist Leslie Klinchuch, with Chevron Environmental Management Co. "Installation factors, technology performance, and durability will help us determine whether we can make even better use of other remediation sites." ■

Please see the video at Chevron.com/Next/Brightfield.

Bright Minds, Bright

Fostering innovations in energy efficiency

Chevron and the University of California, Davis (UC Davis) have a long, successful relationship dating back to the 1970s. Through the years, the two organizations have established key partnerships, based in part on the university's proven ability to turn new developments in its research labs into solid commercial ventures. Areas of cooperation currently include the UC Davis Energy Efficiency Center and its affiliated technology centers, as well as the Biofuels Joint Research Program. The university also is a core school in Chevron's University Partnership Program.

Energy-efficient technologies

Chevron has been a Leadership Sponsor of the UC Davis Energy Efficiency Center (EEC) since 2007. The world's first university Center of Excellence in energy efficiency, the EEC, with its partners, accelerates the development and commercialization of energy-efficient technologies and trains future leaders in energy efficiency.

In 2009, the relationship between the two organizations took an important step forward when the company contributed $2.5 million to endow the center's Chair in Energy Efficiency. Following a nationwide search, Nicole Biggart, Ph.D., was selected in June 2010 to fill this critical role. Professor Biggart will serve as the EEC's permanent director, working to expand the impact of the center's research, education, commercialization and outreach. An expert in organizational theory and innovation management, Biggart has conducted wide-ranging research into the social basis of technology adoption. She has written seven books in her field, published more than 30 scholarly articles and frequently presents at international meetings.

"The UC Davis Energy Efficiency Center is uniquely positioned," said Biggart. "We have deep research connections worldwide and venture links with entrepreneurial hubs like Silicon Valley and Sacramento's clean-tech sector."

Biggart added, "Chevron's endowment will help ensure that our strategic research continues as we work toward our goal of commercializing groundbreaking energy-efficient technologies."

Additionally, the company helped to endow the Arthur H. Rosenfeld Chair in Energy Efficiency, which over time will support the research and other work of an exceptional faculty member.

"Chevron is pleased to contribute to the work of the EEC," said John McDonald, Chevron vice president and chief technology officer. "Advancing energy efficiency, which is the cheapest, cleanest and most

At the California Lighting Technology Center, a UC Davis student works on a prototype for Professor Michael Siminovitch's class in energy-efficient LED (light emitting diode) luminaire design.

PHOTO: KATHREEN FONTECHA/CALIFORNIA LIGHTING TECHNOLOGY CENTER/©UC DAVIS

In June 2010, Nicole Biggart, Ph.D., was selected as the first Chevron Chair of Energy Efficiency.

Future

abundant form of new energy, is critical to the challenge of meeting the world's growing energy needs. California has been a pacesetter in energy efficiency, so it is fitting that one of the state's leading universities and California's largest company should partner on the next generation of energy efficiency."

Light

One of the EEC's affiliated technology centers, the California Lighting Technology Center, works to facilitate and accelerate the development and commercialization of energy-efficient lighting and daylighting technologies. The center provides a variety of educational activities and outreach with such partners as utility companies, lighting manufacturers and government agencies.

Net-zero energy

Chevron helped shape the energy strategy and leads the energy team for UC Davis West Village, a public-private housing and commercial development adjacent to the campus.

This new, approximately 220-acre (89-ha) mixed-use district will become one of the nation's first "net-zero energy" communities, integrating sustainable design to enable residents to reduce their reliance on the automobile and limit energy consumption.

"Chevron is pleased to be a participant in this innovative endeavor," said Jim Davis, president of Chevron Energy Solutions Co. "We applaud UC Davis and the West Village Community Partnership on their long-term, strategic goal to create a pathway to an affordable and sustainable net-zero energy community."

Second-generation biofuels

In 2006, Chevron formed a strategic collaboration with UC Davis to explore the potential of second-generation biofuels in transportation. Made from nonfood agricultural and forest byproducts or municipal solid waste, second-generation biofuels are likely to play an important role in meeting the world's growing energy needs.

Through this program, Chevron supports a broad range of UC Davis scientists and engineers with funding of up to $25 million through 2013. The collaboration involves research to develop commercially viable processes for producing transportation fuels and a demonstration facility to test the commercial readiness of these emerging technologies.

University partnerships

One of California's leading research and educational facilities, UC Davis is a core school within Chevron's University Partnership Program, which includes 18 universities around the world with which the company works closely for recruitment and research.

"Energy is a collaborative venture. The best solutions are built through partnerships," said Melody Meyer, president of Chevron Energy Technology Co. "Chevron is pleased to support the work of outstanding universities like UC Davis and other research facilities. Through their commitment to innovation, they are helping change the way the world uses energy." ■

Visit UC Davis' centers of innovation and hear a Chevron energy efficiency success story at Chevron.com/Next/UCDavis.

University of California, Davis.

PHOTOS, FROM TOP: NEIL MICHEL/AXIOM PHOTO DESIGN/©UC DAVIS; DEBBIE ALDRIDGE/©UC DAVIS

Rising to the Occasion

Young Chevron engineers and scientists make their mark

The energy industry faces some tough obstacles. By 2030, global energy use is estimated to grow nearly 40 percent. To meet this increasing demand, the industry will need to drill in ever deeper and more technically difficult places while at the same time intensifying efforts to discover and develop alternative sources of energy. Compounding the difficulty, many of the industry's most innovative and knowledgeable thinkers are edging closer to retirement.

Where will this next generation of technical leaders with the passion and vision to meet these looming circumstances be found? Here are six portraits of human energy at Chevron—young scientists and engineers who are already making a difference.

PHOTO: OLUKAYODE OLUFEMI

Djuro Novakovic: Puzzle Solver

Djuro Novakovic leads a team of reservoir simulation engineers, supporting Chevron's exploration and development activities in Nigeria and the mid-Africa region. In that capacity, he and his group perform comprehensive reservoir studies to determine where to drill wells and how to optimize production.

Before his assignment in Africa, Novakovic was part of the asset team that worked on the early stages of the Perdido deepwater wells in the U.S. Gulf of Mexico, now in the final phase of development. He also worked on the Jack 2 well, which was successfully drilled to more than 5 miles (8 km) total depth, making it at the time the deepest test well in the gulf.

"Reservoirs are vast, and the data we have to understand them are always limited," said Novakovic. "Our work involves putting the clues together to figure out what the reservoir is telling us. Based on our understanding, we then create a series of simulation models that will allow us to predict the optimal well location and depletion scenario, enabling us to drill the well safely while creating the most value with the appropriate level of investment. In that respect, we're a bit like Sherlock Holmes. We examine the evidence, analyze it and solve the puzzle."

Novakovic has worked for Chevron for eight years. He did his undergraduate work at the University of Zagreb in Croatia and has a master's degree and Ph.D. in petroleum engineering from Louisiana State University.

Laura Verduzco: Carbon Mitigator

Currently, Laura Verduzco divides her time between Chevron Energy Technology Co. (ETC) and Catchlight Energy LLC, a Chevron-Weyerhaeuser joint venture to develop the next generation of renewable, cellulose-based transportation fuels from nonfood sources.

As a lead planning engineer in ETC, Verduzco develops and supports a wide variety of tools, models and work processes to aid decision making related to climate change and sustainability. She helps identify potential improvements in greenhouse gas mitigation and monitoring and assists with the implementation of government policies. At Catchlight, Verduzco coordinates policy between the two parent organizations and various U.S. federal and state regulators to help avoid unnecessary impediments to the production of biomass and its conversion into biofuels.

Among her recent accomplishments, Verduzco managed Chevron's response to the 2009 Carbon Disclosure Project, the world's only global climate change reporting system. "It was a huge effort, requiring us to collect and collate data from every part of the corporation," said Verduzco. "Based on our comprehensive reporting, Chevron ranked first among energy companies on its level of carbon disclosure and was fifth overall among all respondents."

Verduzco is a four-year Chevron employee. She has an undergraduate degree in chemical engineering from Universidad Nacional Autónoma de México and a doctorate in engineering management from the George Washington University in Washington, D.C.

PHOTOS, FROM TOP: MARILYN HULBERT; PAUL S. HOWELL

Umut Ozdogan: Global Field Hopper

Umut Ozdogan is the subsurface leader for the Kuito life-extension development in Angola's deepwater Block 14, a major capital project with important reserves for Chevron and its partners. In that role, Ozdogan works to optimize subsurface and subsea elements of field development by performing reservoir forecasting for facility redesign.

In his six years with Chevron, Ozdogan has been involved with a series of major development optimizations, beginning with Tahiti in the deepwater Gulf of Mexico and continuing on to Tengiz in Kazakhstan and Agbami in Nigeria, then back to the Gulf of Mexico for the Jack and St. Malo deepwater developments. He worked at Angola's Takula Field, which has produced more than 700 million barrels of oil to date.

"We have developed and deployed advanced, highly practical forecasting technologies to address key asset management and project decisions for both brownfield and greenfield development," said Ozdogan. "But for me, what makes Chevron great is not just its strong portfolio of projects or the advanced technologies; it's also the tremendous diversity of people who work here."

Ozdogan did his undergraduate work at Middle East Technical University in Turkey and has a master's degree in petroleum engineering from Stanford University in California.

Next Generation

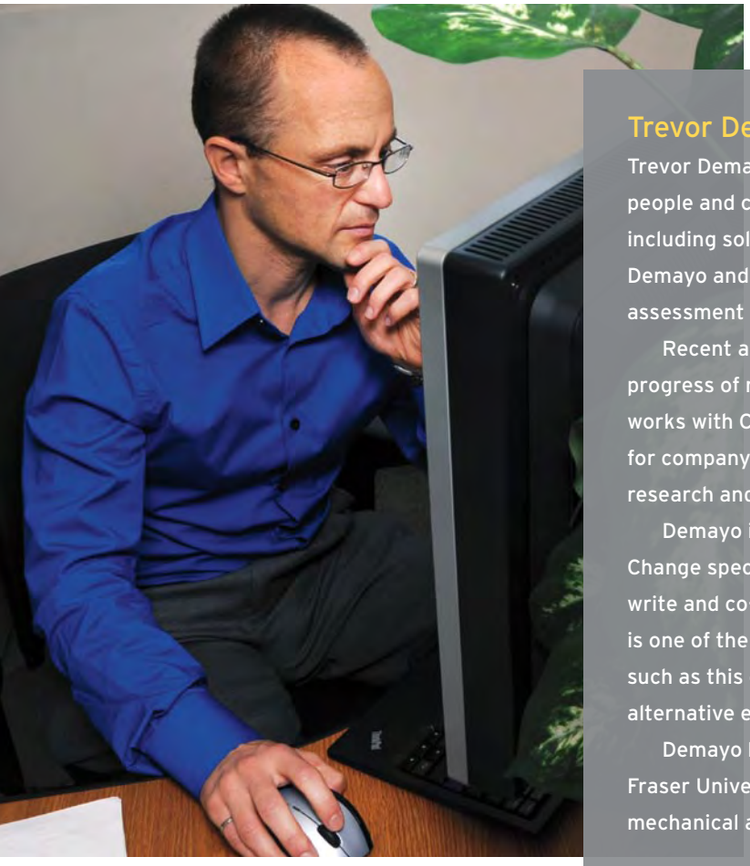
Krista Heidersbach: Corrosion Fighter

Krista Heidersbach faces a tough situation. She manages corrosion-related research within Chevron, with a significant focus on top-of-the-line corrosion, which occurs in wet-gas pipeline systems when water carried by the gas condenses during transportation, damaging the pipeline.

According to Heidersbach, this problem is especially prevalent in the Asia-Pacific region and Australia's North West Shelf, costing the industry millions of dollars annually in pipeline replacements. Heidersbach is also actively involved in research on corrosion caused by microorganisms found in seawater that compromise nearly every engineering metal and alloy used offshore.

Recent projects include a wet-gas pipeline system in Thailand. She has worked on major offshore capital developments in Angola, Nigeria and the U.S. Gulf of Mexico. "Through our research, we are gaining a better understanding of the various causes of corrosion and the steps we can take to prevent or mitigate it," said Heidersbach. "Corrosion is a big problem, and we have a constant goal—making sure pipe can last for the design life of the project."

Heidersbach, a nine-year Chevron employee, received her bachelor's degree from Southern Methodist University in Texas and has a Ph.D. in engineering science and mechanics from Pennsylvania State University.



Trevor Demayo: Alternative Energy Investigator

Trevor Demayo leads ETC's low-carbon energy team. In that capacity, he supervises four people and collaborates extensively, performing due diligence on various alternatives: including solar, wind, geothermal, nuclear, fuel cell and electric vehicle technologies. Demayo and his team project future energy trends, developing economic and technical assessment models to help guide Chevron's strategic planning.

Recent activities include a project in Angola to eliminate gas flaring by tracking the progress of reduction plans and reporting the results to senior management. Demayo works with Chevron's university partners, helping to rank and prioritize research proposals for company funding and developing strong collaborative relationships in advanced energy research and development.

Demayo is currently representing Chevron on the Intergovernmental Panel on Climate Change special report on renewable energy sources, for which he and his team are helping write and co-edit chapters on geothermal energy, bioenergy and transportation. "Chevron is one of the few companies involved in coordinating this effort," said Demayo. "Projects such as this one underscore the seriousness of our commitment to studying and promoting alternative energy among virtually the entire range of potential applications."

Demayo has been with Chevron since 2003. He did his undergraduate work at Simon Fraser University in British Columbia, Canada, and has a master's degree and Ph.D. in mechanical and environmental engineering from the University of California, Irvine.

PHOTOS, FROM TOP: PAUL S. HOWELL; MARILYN HULBERT

Dulcineia Carvalho: Modeling Maven

Dulcineia Carvalho is an information technology (IT) architect for oil and gas exploration and production. For the past two years, she and her colleagues have worked on the architecture framework for exploration and production, a cohesive set of business and information models for standardizing, integrating and simplifying IT systems across exploration and production activities.

"We are developing an architecture that functions as a frame of reference for the integrated operation of IT systems, enabling business objectives to be achieved more efficiently and effectively," said Carvalho. "Ultimately, our work will develop an infrastructure so lean, robust and adaptable to change that will be invisible to the core business."

Among her other accomplishments, Carvalho has worked on Chevron's *i-field*™ initiative for emerging production technologies, helping establish a key software-integration facility at the University of Southern California. This initiative uses new developments in real-time technology, including downhole sensors that allow continual adjustments to wells based on current conditions.

Carvalho joined Chevron in 2007. She has a bachelor's degree in electrical engineering from Agostinho Neto University in Angola and a Ph.D. in computer science from the University of Illinois at Urbana-Champaign. ■

PHOTO: TOMMY LYLES

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