

Next*



* The Next Generation of Energy Technology

The Digital Oil
Field Goes Global

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Issue 5, September 2012

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Welcome

Enabling Energy for Human Progress

Energy that is reliable and affordable is fundamental to human progress and economic prosperity. Energy drives virtually every aspect of the global economy. Indeed, it has been behind the great advances in living standards and societal growth throughout recorded history, especially in the past 150 years. The demand will continue to rise: By 2035, world energy consumption is expected to increase by more than 40 percent as the world's current population of 7 billion surpasses 8.5 billion.

People around the world have come to expect ready access to this energy as they aspire to a better quality of life. It is an expectation made possible by the enormous scale of the world's energy infrastructure, though largely invisible to end users. Meeting this demand in the future will require the capabilities and technology to find, develop, produce, process, transport and deliver energy from many sources, affordably and at scale. And as demonstrated in this issue of *Next**, Chevron is working on innovative technologies across the energy spectrum to do just that.

In Upstream, advanced developments—such as proprietary seismic imaging and enhanced drilling and completions technologies—help us find and produce resources more effectively and with a smaller environmental footprint. These advancements enable us to be a leader in exploration success. Downstream, we are building on our legacy of pioneering technologies that can process the most challenging feedstocks, allowing us to expand our production of high-value premium base oils and other products for global markets.

As highlighted in our cover story, we are transforming our operations through digital connectivity—making strategic investments in digital infrastructure, real-time communication, collaboration workflows and other technologies that are revolutionizing our ability to operate remote fields safely and reliably. We also are investing in new technology pathways focused on greater energy efficiency, improved recovery and renewable energy.

As a global energy company, we know that new ideas can come from anywhere, from any industry, at any time. That's why


we take an open-innovation approach to technology development, working in close collaboration with our operations worldwide. We systematically identify, develop, qualify, integrate and deploy technology from our proprietary research, partnerships, joint ventures and venture capital investments.

This approach allows Chevron access to the most innovative and cost-effective ideas, what we call “human energy.” It ensures that we can deploy the right technology in the right place at the right time—to differentiate our performance and economically deliver the energy that fuels human progress.

Sincerely,



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



Chevron's partnership with
Los Alamos National Laboratory
enables Chevron to uniquely
apply **advanced technologies** to
oil field applications.

When visiting Chevron's Inficomm partner, Los Alamos National Laboratory, Chevron Chairman and CEO John Watson explored this 3-D holograph and other displays.

PHOTO: MANNY GONZALEZ

Cross-Industry Collaboration Fosters Innovation

Through a partnership with a leading research facility, Chevron develops and applies technologies in creative ways

A commitment to partnership is a central value and a major source of strength for Chevron. Innovative partnerships, based on cooperation and trust, give the company access to complementary R&D capabilities while providing resources that can help the partner bring breakthrough ideas to fruition. Together, they find ways to identify, develop and apply appropriate technologies—both new and repurposed—to unlock the additional energy resources society needs.

One such partnership, Chevron's collaboration with Los Alamos National Laboratory, dates back to 2004 and enables Chevron to take advanced technologies, such as those developed for the U.S. military, and apply them in unique ways for the oil field.

"Through these partnerships, Chevron gains access to some of the world's brightest minds," said Manny Gonzalez, alliance manager at Chevron Energy Technology Co., who oversees Chevron's relationships with government labs and universities. "These partnerships can spin off entirely new technologies and lead to new applications."

Data From the Depths

The newly commercialized Inficomm™ communication system shows how this collaborative process can work. Inficomm technology began as a project within Los Alamos for use in military communications.

To develop it for downhole use, Chevron turned to its Area 52™ research facility. "Comprised primarily of recently retired Los Alamos scientists, Area 52 provides us with a prototyping facility that can rapidly transfer Los Alamos technologies into oil field reality," said Scot Ellis, Chevron's Area 52 and Inficomm project manager.

Inficomm technology is now being marketed by Production Sciences, Inc., a spin-off company launched via an exclusive technology license by Chevron. Its signature product reliably transmits real-time pressure and temperature data from depths as great as 25,000 feet (7,620 m). A companion product, TruDepth™ (previously known as Infilevel™) technology, identifies oil and water levels in a pumping well. Unlike current systems, neither requires batteries or wires running from the surface to the bottom of the wellbore. That makes them less expensive than current industry sensors, and because failure-prone communication wiring has been eliminated, they do away with traditional reliability problems.

"Inficomm and TruDepth technologies provide a huge benefit for engineers managing oil reservoirs," said Ben Bloys, Chevron's manager for the Los Alamos alliance. "Accurate readings will help enable engineers to economically measure critical indicators of the health of all types of wells and resolve potential problems early on."

Both Inficomm and TruDepth technologies are part of a pilot program in Chevron's San Joaquin Valley operations in California.

"Early indications are that the Inficomm system will be an important technology for production and reservoir management in ultra-hot wells composed of diatomite minerals," said Braidon Waggoner, a Chevron project lead in the San Joaquin Valley. "At the same time, TruDepth technology, with its straightforward approach, is enabling us to better manage Chevron assets by providing cost-effective monitoring and evaluation not previously available to our industry."

Looking Ahead

"We are pleased to support the work of outstanding research facilities like Los Alamos National Laboratory," said Gonzalez. "Energy is a collaborative venture, and some of the best solutions are built through partnerships. By working together, we can review existing technologies developed for other applications. Then, if any light bulbs go on, we can move rapidly to deploy those game-changing technologies within our operations."

The Chevron-Los Alamos alliance has been recognized for its successful collaboration and achievements. It won the Federal Laboratory Consortium's 2012 Award for Excellence in Technology Transfer for developing and commercializing Inficomm. ■

Capturing Data in Motion

Chevron's powerful software gives analysts an advantage in making critical Downstream decisions

Consider the variables needed to produce a gallon of gasoline. Thousands of factors across the supply chain need to be weighed. Crude oil from different regions of the world comes in a variety of grades. Each grade includes different elements. Crudes have different prices. Refineries are configured to handle various types of crude to make different products. With prices of crude oil and natural gas constantly in flux, calculating equations based on all these variables simultaneously is beyond the abilities of any human brain.

To meet this challenge, Chevron engineers designed a remarkable system called Petro. Analysts trained in running the software work in refineries and next to traders in each of Chevron's trading hubs in Houston, London, San Ramon and Singapore. Petro

considers a long list of dynamic variables and helps the analyst advise traders on whether a particular bid makes sense at that time. And Petro helps analysts decide which processing equipment will best take advantage of every part of the barrel of oil.

Chevron was the first to develop this type of technology and, in the 1980s, to move the program off mainframe computers and onto personal computers. Since then, Petro's challenge has grown to be as broad and varied as Chevron Downstream (product refining, transportation, trading and marketing) itself.

The Supply and Demand Equation

The crude-to-customer supply chain begins in oil fields around the world. Crude oil, some of which is Chevron's production, goes to Chevron refineries where it is made into a

spectrum of products ranging from gasoline, diesel and jet fuel to base oils that are later blended into lubricants, additives and other products. Much of the refineries' output is sent to terminals, where it is then sent on to industrial customers and retail outlets. Natural gas, also purchased on the market, is needed to fire refinery furnaces and produce hydrogen for refining.

Petro allows analysts to explore more planning alternatives, arrive at the best recommendations and do all that faster than with other refinery planning technologies.

For good results, Petro requires good data—provided courtesy of Chevron's testing labs. Chevron's refineries accept crude of different types from all over the world—about three-quarters of it from oil fields outside the company. Raw material from each field has a different molecular makeup. And as the field matures, the chemical composition can change. So every day, samples arrive at Chevron's labs for testing.

Petro processes 400 to 500 variables associated with crude oil characterization, along with thousands of refinery-capability variables, to arrive at the best solution—and all within a few seconds. Planners analyze the results before recommending a course of action.

Process experts at each refinery are constantly updating Petro to reflect changes in crude oil properties, the refinery's processing capabilities, and government and industry specifications. Typically, these analysts are chemical engineers with about 10 years' experience—usually in refining—who



Planner Michael Deleon uses Petro to understand the effects of refinery configuration and constraints on crude oil refining values. The information helps traders buy the highest-margin crude for Chevron refineries.



Chevron consulting engineer and Petro's chief architect, Ted Kutz (center), discusses methods for modeling gas-stream processing with planning analysts Ann Ciurczak and Nick Kenaston at the Richmond Technology Center.



Traders—such as John Kuehn (left), general manager for crude trading in the Americas, and Freeman Shaheen, global manager for sour crude trading—provide market forecasts that planners import into Petro. Petro values are then compared with trading models.

have a strong understanding of the manufacturing business.

Petro's Scenarios

Factoring in market prices for product is important as well. "The market is dynamic for natural gas, gasoline and crude oil," said analysis team leader Mark Davis. "Petro helps you shift your operations to capture the best economic point, whereas if you operated under an accepted paradigm, you'd miss opportunities or be slow to capture them."

Analysts also use Petro to see what happens when key variables change. Recently, Ted Kutz, Chevron's refinery optimization expert and Petro's chief architect, did just that. In a work session with California's Air Resources Board staff, Kutz presented scenarios based on different fuel mixtures that the agency was considering for future regulations. He explained how certain fuel recipes could result in lower gasoline production and higher operating costs, which

could lead to higher prices for consumers. Based on Petro's report, Kutz showed how other formulations had less impact on supply and cost while meeting the board's environmental targets.

In the early days, one analyst would spend a half-hour setting up a question and wait two or three hours for a paper report an inch and a half thick. Only then could the analyst mull over the results. Now, the program is used by up to 200 people at once while processing as many as 10,000 equations. And thanks to ever-increasing computing power, it takes only three minutes to set up a report and two or three seconds to see the results on screen. No longer data entry clerks, analysts now spend most of their time actually analyzing.

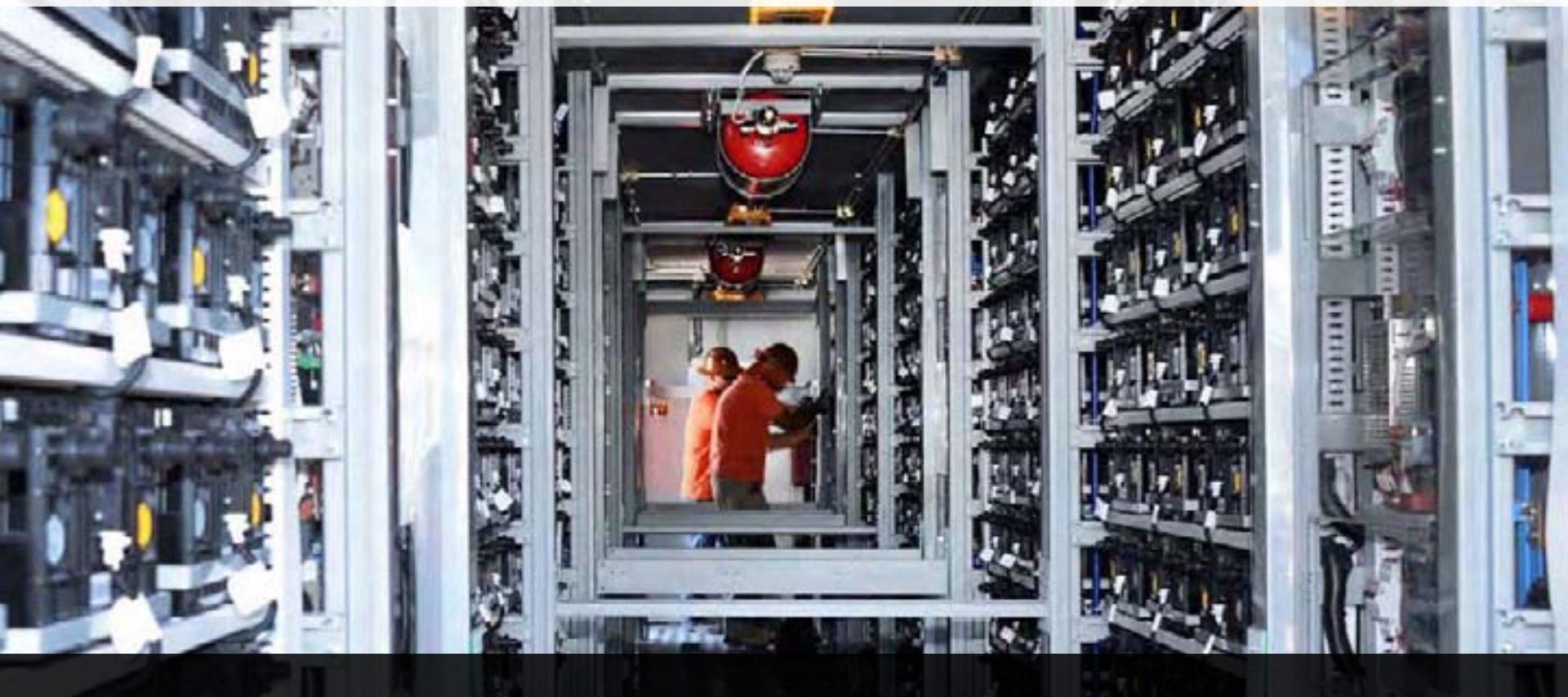
There's also an element of social networking to Petro. The ability to quickly share information has allowed for more collaboration.

Ultimately, it's the people who make Petro work. As a tool, Petro is only as good as the analysts who use it.

Kutz used an analogy: "In boxing, a sparring partner helps train the boxer, and the same goes for Petro," he said. When looking at a Petro report, "a good analyst will ask himself 'Did Petro confirm my expectation? If not, why not?'" According to Kutz, "Petro supports the premise from a good analyst 80 to 90 percent of the time. But sometimes, nuances reveal something unexpected and point to a better course of action. It's one way we're using technology to differentiate Chevron's performance." ■

Petro processes 400 to 500 variables associated with crude oil characterization, along with thousands of refinery-capability variables, and all within a few seconds.

Electrical workers inspect the inside of the 53,000-ton battery container following the equipment lift.



Keeping the Lights on at Santa Rita Jail

Chevron designs and builds one of the United States' largest microgrids, demonstrating a new model for power reliability

A row of nondescript buildings in the dry brown hills of Northern California, Alameda County's Santa Rita Jail became a national model for energy security in March 2012, when the facility switched on a "smarter" electrical grid. This microgrid, which incorporates simplified controls and large-scale renewable and clean energy generation with a 2-megawatt-capacity battery, was designed and built by Chevron Energy Solutions (CES), Chevron's subsidiary for energy efficiency and renewable energy solutions. One of the country's largest microgrids, this is a first-of-a-kind project involving multiple technologies and partners, including Chevron, the U.S. Department of Energy (DOE), the California Energy Commission and the California Public Utilities Commission.

"The grid's large onsite battery is charged during off-peak times and discharged during peak times. It has a very fast switch that enables it to respond to grid outages in milliseconds and separate the jail from the utility," explained Dave Potter, CES senior project director for Western Region operations. "This provides the facility with a self-sustaining grid that integrates all of the jail's onsite generation with energy storage for uninterrupted power—a critical factor in such an environment."

In the event of a disturbance to the utility grid, the jail can automatically disconnect from the grid and operate under its own power until reliable power from the local utility is restored.

The completion of the microgrid is the culmination of several projects involving Chevron and Alameda County that date back to the 2001 California energy crisis.

In 2002, Chevron's energy efficiency work enabled the funding of a 1.2-megawatt solar photovoltaic system—one of the largest of its kind at that time—on the jail's rooftop. Three years later, Chevron installed a 1-megawatt molten carbonate fuel-cell cogeneration plant at the jail, providing both ultra-clean energy and waste-heat recovery while saving local government more than \$260,000 a year and benefiting the environment. That project was followed by the implementation of energy efficiency and water conservation measures and the installation of five small wind turbines, adding to the jail's renewable energy capacity.

The **microgrid** is the culmination of several **alternative energy projects** Chevron installed at the jail, including a **1-megawatt fuel-cell cogeneration plant** that provides both **ultra-clean energy** and **waste-heat recovery**.

Meanwhile, Chevron's partners provided funds for Chevron to build on this remarkable facility by designing and installing a 2-megawatt battery and automatic disconnect switch. This enables the facility to run under a platform based on a simplified control scheme, allowing the facility to seamlessly remove itself from the main utility grid and independently generate and store energy for its own use. This development advances the DOE's goal to deploy an interconnected energy network.

"This project is comparable to the computer-industry shift from the main frame to the desktop," said Eduardo Alegria, Chevron senior engineer for power systems. "In this case, we switched from a centralized grid system to a decentralized one enabled by distributed, renewable generation and large-scale energy storage."

Through this project, CES is gaining valuable experience that can be applied to Chevron facilities as well. "Microgrid projects like this one may have applications for Chevron operations in other regions of the world," Alegria added.

Its ability to deploy new technologies in innovative ways is one reason why CES remains among the top energy services companies in the United States.

"Over the past decade, we've applied our experience to improve operations at our own facilities, too, and we expect to add even more value in the future," Alegria said. ■



Top left: At the March 22, 2011, dedication ceremony, Keith Carson, District 5 supervisor and vice president of the Board of Supervisors, Alameda County, said, "The Smart Grid project highlighted the role that public-private partnerships can play in creating innovative solutions that will help Alameda County reduce costs while also saving energy, preserving our environment and promoting energy independence." Top right: Kyle Stavis (left), associate construction manager of Strawn Construction, reviews the schematic for Santa Rita's grid with contractor Chuck Garvin. Bottom: King Crane Service's ironworker Leigh Matson (left) and oiler Dwight Hill discussed how they would rig the battery containment unit during installation.

Santa Rita Jail




The energy efficiency improvements at the Santa Rita Jail are also earning kudos from the community.

See how the Santa Rita Jail generates reliable power from a variety of energy sources at Chevron.com/Next/PowerGrid.



The Digital Oil Field Goes Global

Technology and
connectivity deliver the
best minds to Chevron
operations anywhere
in the world



High in a Houston office tower, the info-tech-savvy team at Chevron's Machinery Support Center (MSC) monitors thousands of pieces of equipment on six continents in real time, including hundreds of units in Kazakhstan and two massive compressors in Colombia that deliver enough natural gas to supply approximately 65 percent of that nation's demand.

Stuffed with screens and software, the new nerve center is already making a difference. Each day, for example, operators at Chevron's big Sanha Field off the coast of southern Africa inject millions of cubic feet of natural gas, an essential task at a complex facility that produces millions of barrels of ultra-light oil per year. When a compressor recently showed subtle signs of overloading, the first person to notice was 6,000 miles (9,656 km) away in the MSC.

The busy crew at Sanha would have found the problem, but now this and other Chevron Upstream operations have solid backup to detect any similar situations in other locations with the teams and technologies at the global MSC, which evolved from an earlier surveillance center conceived to monitor compressors in the Gulf of Mexico and California.

"The crew acted on the MSC's tip and avoided a couple of million dollars in downtime and lost production," said Fred Schleich, machinery and electrical power system manager at Chevron Energy Technology Co.

Until recently, the MSC was just a proposal. Today it's one of several elaborate technology solutions in an orchestrated Chevron initiative called Upstream Workflow Transformation, or UWT. The new program follows a decade of investment in infrastructure and instrumentation—mostly in Chevron's North America operations—under a broad business priority known as the digital oil field. Now the company wants to extend the proven solutions and safety gains from its U.S. oil and gas fields to its operations on six continents.

Big Prizes Await the Winners

Helped by other companies—Microsoft, SAIC, Schlumberger and more—Chevron set out to reinvent and automate operations using existing, emerging and yet-to-be-developed

technologies and workflow enhancements, said Mike Hauser, program manager of Chevron's UWT effort. Major competitors did the same. Industry results to date suggest big prizes await the winners of this race: up to 25 percent in operating cost savings, up to 8 percent higher production rates, 2 to 4 percent lower project costs, and as much as 6 percent improved resource recovery within the first full year of deployment, according to IHS-CERA, which tracks projects at a dozen companies, including Chevron.

"Chevron has been a leading light, one of the early industry drivers, and they've worked methodically and thoughtfully to become one of the top three companies working on the digital oil field," said Judson Jacobs, longtime leader of the IHS-CERA Digital Oil Field of the Future forum.

Pioneered in North America, Chevron's original *i-field*™ digital oil field effort delivered hundreds of millions in cost savings and improved output since 2002. Challenged by company leaders, employees and teams in California, Texas, the Gulf of Mexico and other locations turned fields and facilities into i-field laboratories, incubators and proving grounds to transform and reinvent workflows.

"We used technology to change what we do, rather than optimize what we have always done," said Jim Williams, one of several key managers who led and inspired Chevron's first forays into the digital oil field.

Becoming Lean

The Carthage Field in Texas, Kern River Field in California and Captain Field in the United Kingdom, among others, became i-field digital oil fields. At the same time, Chevron sponsored the Center for Interactive Smart Oil Field Technologies at the University of Southern California, initiating research, hiring graduates, hosting interns and helping employees earn degrees and certificates. As digital oil field technology evolves, Chevron is committed to evolving with it, said Paul Siegele, president of Chevron Energy Technology Co.

25
percent

Potential cost savings
from UWT workflow
enhancements and enabling
technologies in the first
year of deployment



The Captain Field in the U.K. North Sea is an i-field digital oil field. Seen here is the main deck of Captain's bridge-link platform.

Meanwhile, the entire digital oil field effort has been enhanced by a simultaneous focus on streamlining key business processes through techniques such as Lean Six Sigma. Indeed, said Brian Cabote, who coordinates Chevron's UWT effort in the Gulf of Mexico, digital oil fields can perform their best only when companies integrate streamlined processes with people, technology and information.

"We're confident that our improvements and results to date make a strong business case for taking the i-field program global," said Gary Luquette, president of Chevron North America Exploration and Production Co.

The trend isn't just about profit. Achieving what's come to be known as "intelligent energy" operations is also about increasing world energy supplies. According to the International Energy Agency, by 2035 oil demand will rise by nearly 20 percent, gas demand by nearly 60 percent, and electricity demand—much of it fueled by gas—also by almost 60 percent.



‘Our improvements and results to date make a strong business case for taking the i-field program global.’


– Gary Luquette, president of Chevron North America Exploration and Production Co.

Savings from digital oil fields create more capital for energy investment. Higher field reliability helps ensure safer operations, more accurate production forecasts and steadier energy supplies for businesses and consumers. Automation raises field productivity and optimizes experts’ knowledge. Given the potential benefits to Chevron’s customers, partners and stockholders, no wonder it’s called intelligent energy.

Ultimately, some 300 full-time employees throughout the company will support Chevron’s new, five-year plan, anticipates UWT general manager Dave Dawson. Six to eight global solutions are projected to improve performance at the biggest, most productive fields in more than 40 locations, giving Chevron an edge over competitors, he believes.

RDOC

Consider the new Real-Time Drilling Optimization Center (RDOC) near the MSC in Chevron’s Houston towers. Here, seasoned drilling experts immersed in 360 degrees of live data provide support to drillers throughout the world, monitoring data trends to assist in decision making as wells are drilled. Employees work 12-hour shifts in 14-day rotations, matching crew schedules out on the rigs. As it evolves and the team learns how best to add value, the RDOC will aim to increase safety, efficiency and well quality where it counts most, monitoring, supporting and advising top-priority wells simultaneously across Chevron’s global Upstream operations.

A low-angle, upward-looking photograph of a complex industrial facility. Large, metallic, ribbed pipes and structural beams crisscross the frame, leading the eye towards a bright blue sky. The perspective creates a sense of height and scale.

'Applying ingenuity at speed, we're putting our best minds to the toughest challenges anywhere in the world.'

– John McDonald, vice president and chief technology officer

Chevron is a leader in steam-stimulation technologies. Seen here are pipes at the large-scale steamflood pilot project at the Wafra Field in the onshore Partitioned Zone between Saudi Arabia and Kuwait.

PHOTO: MARK WILLIAMS/UWE WRUCK PHOTOGRAPHY

Ultimately, RDOC could help improve field development efficiency for projects requiring large numbers of similar wells, particularly for heavy oil and shale gas developments. Meanwhile, another solution called Waterflood Surveillance, Analysis and Optimization will focus on improving performance in Chevron's global portfolio of 140 fields that use water-flooding. The fields produced more than 570,000 net barrels of oil per day in 2011.

"Even though each oil field is different, all waterfloods have key operational elements and reservoir management activities that could be standardized globally," said water-flood specialist Ray Clark.

The company's digital oil field vision also includes complex asset management systems incorporating torrents of data and bundles of technologies. Real-Time Production Optimization/Reservoir Management, for example, uses real-time well and subsurface models based in geology and engineering to guide wells, facilities and operating system decisions.

Beyond these initial global solutions, four more are in the works, including the Thermal Decision Support Center to optimize heavy oil production in Indonesia, the United States and the Middle East, where Chevron is a leader in steam-stimulation technologies.

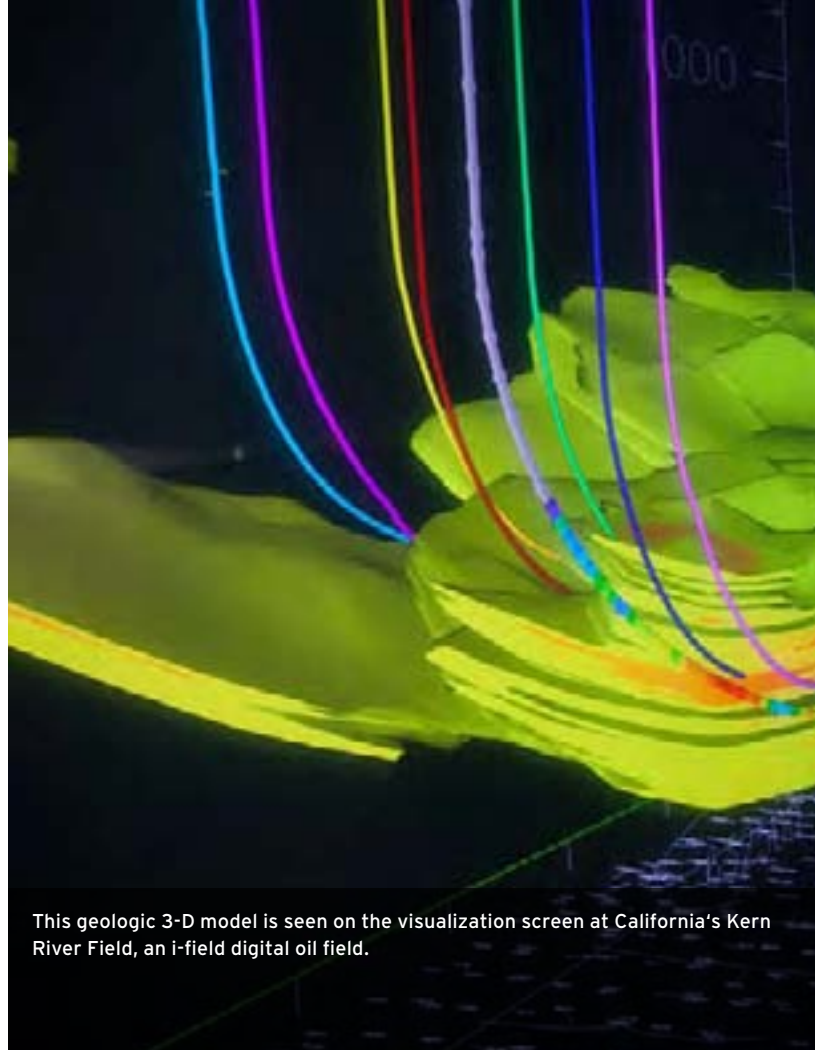
But let's back up a bit. What, exactly, is a digital oil field?

Automation, Integration, Intelligence

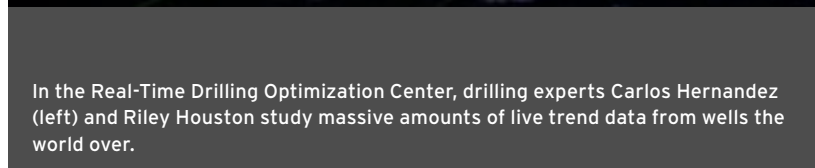
"The vision is real-time monitoring, analysis and control for optimum field management," said Hauser. "We've seen a revolution in sensors to measure what's happening down in the wells and in production equipment and have seen major advances in process instrumentation. And we've connected hardware and data to field performance models, continually analyzing information and making decisions to maximize output."

So it's about automation, but also integration—linking once-separate functions such as maintenance and drilling, and managing them within value chains. This requires streaming all relevant data into asset-decision environments, which fuse humans, data and technologies in a collaborative setting. Said Chevron i-field specialist Darrell Carriger, "Centralized surveillance allows management by exception, which enables a more efficient use of the workforce than manually checking every well and facility."

In addition to novel types of surveillance, new and innovative types of analysis programs search the clues to forecast when equipment will need service, repair or parts. More and better data, converted by software in real time into useful information, also enables another digital



This geologic 3-D model is seen on the visualization screen at California's Kern River Field, an i-field digital oil field.



In the Real-Time Drilling Optimization Center, drilling experts Carlos Hernandez (left) and Riley Houston study massive amounts of live trend data from wells the world over.





Operator Rusyulianto documents performance data at Duri Field's Area 5 central steam station. With the application of advanced steamflood technologies, Duri is one of the most prolific fields in Indonesia.

Chevron was selected by *U.S. News & World Report* as one of America's and gas corporation so named—for its global i-field operations,

oil field essential: better, faster decisions to optimize field performance. A malfunction that might reduce output by 200 barrels in a week is caught and fixed in a day instead.

Making it all possible, said Chevron Vice President and Chief Technology Officer John McDonald, is connectivity—linking data, facilities, people and ideas through information technology and advanced communications.

“Connectivity is not only improving our business, it’s enabling us to improve it faster,” said McDonald. “Applying ingenuity at speed, we’re putting our best minds to the

toughest challenges anywhere in the world, ensuring that we’ll continue to perform better and open new frontiers to help meet the world’s energy needs.”

Case in point: Before the MSC and the RDOC were conceived, Chevron’s Gulf of Mexico operations created an Offshore Logistics Decision Support Center to streamline the constant coordination of vessels, supplies, equipment and people moving between shore bases and hundreds of structures. Within a year of opening, the center was logging cost savings from smarter vessel usage and fleet management, and safety gains as well, said Hauser. UWT is now building an enterprise version of the Gulf of Mexico’s logistics solution for deployment across all major Chevron Upstream operations.

40+
worldwide

The number of projects in which Chevron is investing at least \$1 billion each

Transformation Through Connectivity

Chevron has also recognized the importance of designing and building its major new projects as digital oil fields. The company today has 40 energy developments in which it is investing at least \$1 billion each. Within 10 years, 50 percent of company production is expected to come from today's big projects.



Most Connected Companies—the only oil which are saving several hundred million dollars in operating costs

Recently, intelligent wells and systems were installed to automate and optimize the injection of gas and water into the Agbami Field in Nigeria. And the company's Tahiti deepwater project in the Gulf of Mexico has incorporated digital oil field fundamentals and systems.

"Tahiti achieved maximum oil production rates in a short period of time, proving that incorporating i-field solutions into projects can deliver huge incremental value through increased production and reserves," said Warner Williams, vice president of Chevron's Gulf of Mexico operations.


Currently in the pipeline to further help future projects is Real-Time Facilities Optimization (RTFO). This effort focuses specifically on advanced process controls to enhance efficiency in oil and gas fields while ensuring safety and protecting the environment throughout a facility's lifetime. RTFO leader Mike Barham believes that building upon this capability will give Chevron "sustainable technical and economic competitive advantage."

"We've set a course to fully harvest the potential of the digital oil field," said Hauser. "The global vision is to transform how we operate, with real-time instrumentation delivering

real-time information, allowing real-time implementation of decisions, with processes coordinated to provide innovative solutions to meet the needs of our oil and gas operations."

Not surprisingly, Chevron's people are also being transformed, learning new systems and embracing collaborative behaviors. The company is recruiting the next generation of employees. But as energy companies surge toward the digital oil field future—and invest to deliver new energy supplies—they know that training and recruiting can't fill the whole need for human resources. They must find ways to leverage brainpower and experience more broadly and better integrate functions across the value chain.

Consider, for example, that Chevron's major capital projects are expected to double their global compression capacity by 2015. To make sure that enough expertise is available to cover the larger fleet, the MSC functions as a real-time knowledge-delivery portal, beaming top troubleshooters into hot spots without the time and expense of travel. In effect, they're cloning the company's most seasoned technologists through connectivity. ■

A photograph of Paul Siegele, president of Chevron Energy Technology Co., standing on a rooftop. He is wearing a dark suit jacket over a light blue button-down shirt and glasses. He is leaning on a metal railing. In the background, there is a city skyline with several skyscrapers, including a prominent one with a curved, glass facade on the left. The sky is clear and blue.

Paul Siegele, president of Chevron Energy Technology Co., is responsible for managing research and development and technical support for Chevron's businesses worldwide. He joined the company in 1980 as a petroleum geologist after graduating from California Lutheran University with a Bachelor of Science degree in geology. In 1990, Siegele earned a Master of Science degree in geology from California State University, Northridge.

Taking Technology to New Heights to Meet Future Energy Demand

Vantage Point With Paul Siegele

PHOTO: ED LALLO

Technology development is essential to the energy industry. Advances in technology have allowed us to develop resources that would have been impossible to access just a few decades earlier.

The key to successful technology development is linking innovation with business and operational needs. Our subsidiary Chevron Energy Technology Co. (ETC) partners with our various operations throughout the company to deliver technologies that not only add value but also tackle some of the world's most difficult energy challenges.

ETC allows us to differentiate our performance in our business around the world through the use of technology to improve the reliability of our assets, keep people safe and apply innovative solutions to challenges. Ultimately, we are differentiating our financial performance as well. Our technology strategy has three components: to align with business needs, to protect our intellectual property and to invest in technologies that will position Chevron for profitable growth. To set a clear direction for our technology efforts requires a close alignment with the business needs and a view of the longer-term trends of the global energy outlook.

What the Future Holds

The U.S. Energy Information Administration estimates global energy demand to grow by more than 40 percent by 2035. This growth will come predominantly from emerging markets, including India, China, Brazil and countries in Southeast Asia—areas where large populations are coming out of poverty and emerging into middle-class lifestyles and incomes. Energy is expected to play a key role in this human progress, helping to spur social, economic and industrial growth.

And while renewable energy will play an increasing role in the energy landscape, according to the International Energy

Agency, it is still expected to account for only 15 percent of the world's energy. The lion's share of the need—nearly 80 percent—will be met by the conventional resources of oil, natural gas and coal.

Because of demand growth, supply is being squeezed. It is important to maximize recovery to extend the life of our legacy operations and increase yields in new developments. As more of the conventional supply comes from challenging sources—such as heavy oil, shale, tar sands—and regions—such as the Arctic and the deep-water Gulf of Mexico—innovative technologies will play a critical role in our ability to supply the energy the world demands.

Technology Creates Value

Chevron has deployed technology with impressive results. Our Upstream advances in seismic characterization have enabled our long-term exploration success. Enhanced oil recovery technology and new reservoir-management simulation tools have enabled us to improve recovery rates by more than 50 percent in some areas. In Downstream, advancements in catalysis and hydroprocessing are improving yields. And we're expanding our expertise in base oil with the construction of the \$1.4 billion Pascagoula Base Oil Project in Mississippi.

Employee Ingenuity and Strength

Technology alone isn't enough. Trained people are needed to create and use the technology to interpret and creatively work with the data. Our highly trained technical

workforce is key to our success. Our scientists and engineers work in a collaborative culture to expand capabilities and opportunities throughout our operations. Through our Chevron Fellows and Mentoring Excellence in Technology programs, knowledge and experience from leading scientists and engineers are passed down through structured guidance, ensuring continual technology transfer and capability development. From exploration and production to processing, transport and delivery, our technologists constantly seek advances to keep the energy flowing and find ways to deliver more.

Strategic Partnering

Sound business strategies, targeted funding and a skilled workforce are the basis for successful technology deployment. But in order for us to maximize our innovation effort, it is essential that we build partnerships with other technology organizations, both within the industry and beyond.

By developing research partnerships with universities, national laboratories and research institutions, we gain access to sophisticated engineering research and top-tier scientists to assist with the demonstration, development and commercial deployment of the advanced technologies we'll need to bring on line. The world faces unprecedented energy challenges, but Chevron's capabilities are strong. Our unique approach to managing and deploying technologies in our business will help ensure energy security for tomorrow. ■


40 percent
by 2035

U.S. Energy Information
Administration
estimate of global
energy demand growth



New Technologies Help Tap an Old Resource

In Pennsylvania, Chevron is working to capture and reuse 100 percent of the water used in producing natural gas from shale—just one example of how technology is advancing environmental stewardship and performance



At the site of a reclaimed natural gas field in western Pennsylvania, a producing well leaves a small footprint.



PHOTOS: BOTTOM LEFT, KEN CHILDRESS; TOP RIGHT, MARC MARRIOTT



Chevron's Greg Hild (left), business development manager, and Derek Cragg, completions specialist, discuss operations plans at the natural gas drilling site in Somerset County, Pennsylvania.



While a Chevron drilling rig bores down 8,000 feet (2,438 m) below southwestern Pennsylvania to unlock natural gas trapped in dense shale rock, Tim Svarczkopf monitors the mobile water-treatment technology he invented.

"The process takes black, viscous water that flows back after completion, combines it with production brine that is red from iron content, and turns it into crystal-clear water that looks like it comes out of a household tap," he said.

Svarczkopf is Chevron's manager of water technology in the region. His work is just one example of how the company is applying new technology to optimize well performance and advance environmental stewardship in its Marcellus operations and in other places where the company extracts natural gas from shale.

Chevron began producing natural gas from shale in southwestern Pennsylvania in 2011, when it acquired Atlas Energy, Inc. With more than 700,000 acres (283,300 ha) under lease in the Marcellus Shale, Chevron is one of the state's largest leaseholders.

Unlike conventionally sourced crude oil and natural gas, which have migrated toward the earth's surface from an organic-rich source rock into highly permeable reservoir rock, natural gas forms within shale rock, whose low permeability inhibits the gas from moving upward.

The energy industry has long known about huge gas reserves trapped in these deep formations, such as the Marcellus under Pennsylvania and neighboring states, but the complex geology has left this energy source largely

beyond reach. However, during the past decade, the combination of two established technologies—horizontal drilling and hydraulic fracturing—has dramatically altered the U.S. energy supply picture. Natural gas from shale is the fastest-growing source of natural gas in the United States and could become a major global energy source.

The operation begins as a drilling rig sinks a vertical well more than a mile (1.6 km) below ground. Then the well extends horizontally 2,000 to 5,000 feet (610–1,524 m) into the shale. For each well in Pennsylvania, the process of hydraulic fracturing injects about 5 million gallons of pressurized water along with sand and additives to selectively crack the rock and provide a pathway for the natural gas to travel to the wellbore. This year, Chevron plans to spend millions of dollars on shale research and on technology that will improve the productivity of shale wells.

"We're working on technologies to improve well performance and find superior ways to handle and treat water, all while minimizing the company's footprint on the ground," said Mike Maneffa, Chevron's shale gas asset-class manager.

To improve the productivity of low-permeability reservoirs, Chevron continues to explore the use of specialized proppants and a new fracturing fluid that uses liquefied petroleum gas instead of water. To pinpoint the most promising drilling sites, the company is using seismic imaging to bounce sound waves off the underground rock. Both 2-D and 3-D seismic and microseismic technologies, along with logging and coring data, provide a road map for how the gas can be extracted in a safe and viable way.

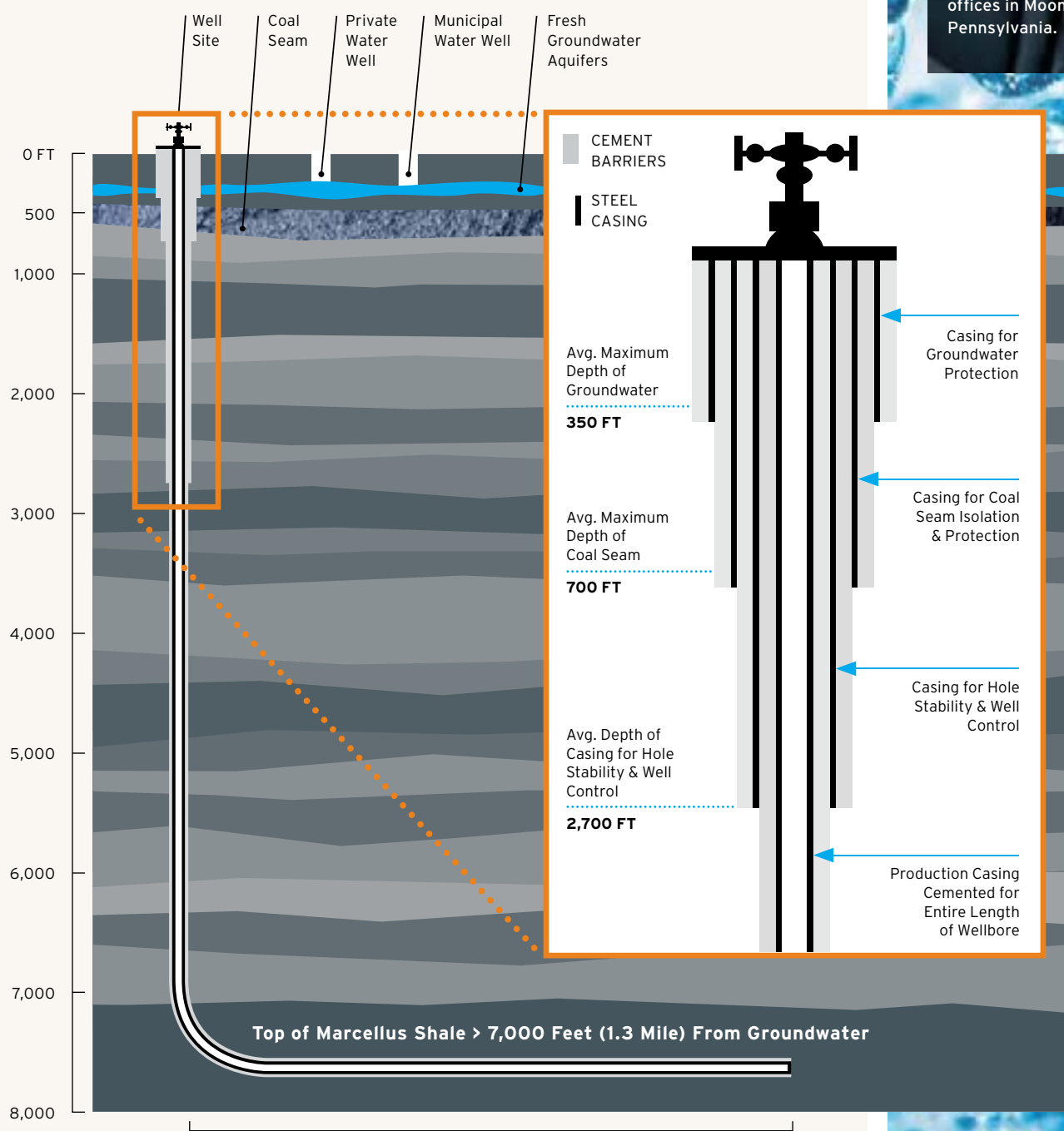
Partnership With Penn State

With Chevron's entry into natural gas development in the state, the company's longstanding relationship with Pennsylvania State University has taken on added importance. Through its University Partnership Program (UPP), Chevron has significantly increased its financial support and presence on campus to help build capacity in petrotechnical disciplines and provide the region with a talented workforce. The UPP also provides funding to Penn State's Marcellus Center, a global thought leader in research on natural gas from shale. The university named Chevron the 2012 Corporate Partner of the Year.

Chevron wells in Pennsylvania are designed to safeguard groundwater with up to eight layers of protection



From left, Geographic Information Mapping staff Amanda Miller, William Alchier, supervisor Jennifer Nelko and Benjamin Gajewski create maps of the Marcellus Shale region from Chevron's offices in Moon Township, Pennsylvania.



1 ft = 0.3048 meter
MARCELLUS LATERAL LENGTH: 2,000-5,000 FEET



"As we understand these formations better, we can make sure we drill only as far as needed. Over the next few years, through technology, we'll be able to selectively fracture with even more precision, which is expected to reduce water needs and the numbers of trucks that haul water," said Mike Power of Chevron Drilling and Completions.

Chevron is applying what it has learned from drilling in the Gulf of Mexico, where its wells have extended more than 30,000 feet (9,144 m) into the earth. Chevron's Real-Time Drilling Optimization Center, pioneered in the Gulf, could help monitor wells drilled on land in Pennsylvania.

"It's an extra set of eyes monitoring operations 24/7," said Power. "This improves the safety of people on location and enhances process safety—everything from rigging up, pumping the frac job and monitoring drilling in real time."

Power said the fractures are more than a mile (1.6 km) below groundwater. To protect groundwater, Chevron's wells in the Marcellus have a combination of as many as eight layers of steel casing and cement that form a seal between the well and the groundwater as drilling telescopes downward.

Investing in Pennsylvania



Chevron's work in the Marcellus Shale in Pennsylvania is developing more than natural gas; it's also fueling job growth and strengthening local economies.

■ See how Chevron produces natural gas from shale at Chevron.com/Next/ShaleGas.

■ Meet Bill Jackson, whose farm is home to a natural gas well, at Chevron.com/Next/MarcellusShale.

Chevron's technology is coupled with formidable safety ethics from the company's Operational Excellence Management System, a comprehensive, proven means of systematically managing process safety, personal safety and health, the environment, reliability, and efficiency.

"Safety is not just a priority, it's part of our culture. First and foremost is the safety of the people on location and process safety—in every task we perform. Environmental protection and operating in a sustainable manner are paramount. It all starts with a robust well design," said Power.

Chevron performs tests over the life of the well to verify its long-term integrity. Before drilling, it also carries out voluntary freshwater monitoring in the areas near its drilling locations that exceeds state requirements. Analyzing that data will help Chevron and others understand the water-quality conditions before, during and after drilling.

In the Marcellus, there has been a concerted effort to reduce the number of additives contained in the fracturing fluids, which make up less than 1 percent of the water and sand mix used during the hydraulic fracturing process. Thanks to Svarczkopf's efforts, Chevron now uses fewer chemicals in its fracturing fluids, reducing the number required by 77 percent.

Chevron is working to capture and reuse 100 percent of the fracturing fluids and water produced with the natural gas.

"The technology enables us to reach this goal, and we're investing in infrastructure that will allow us to do that," said Svarczkopf. "Chevron's emphasis on operational excellence and environmental consciousness made it an easy sell when I asked for funds to advance the technology."

Capture and reuse reduces freshwater consumption as well as the need for water trucking, transfer and disposal. Chevron also has started using water pipelines to lessen the need for tanker trucks to transport water.

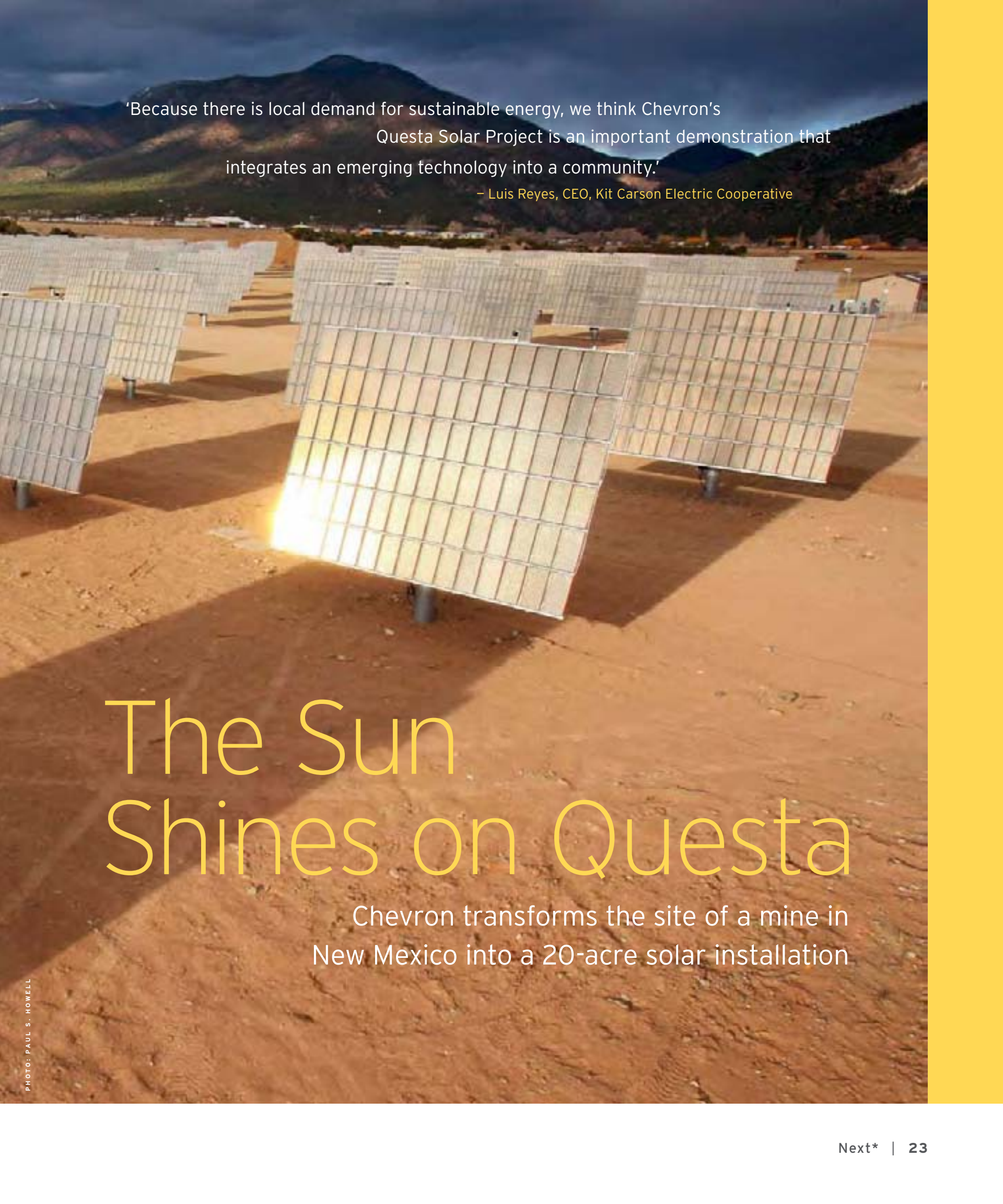
"By treating water right on our pad, we can take water from one well to another, reducing truck traffic by half," said Svarczkopf. He also is working to convert pit-based water-treatment systems to deconstructible vertical tanks, which would be in place for 20 weeks and then moved to another site. This system would diminish the drilling-pad footprint and reduce reclamation needs.

Most wells are built and completed within a year. Afterward, Chevron works with the landowner to restore the property's original contours and minimize any other above-ground impacts. Hydroseeding helps to reestablish the indigenous grass more rapidly.

It's a holistic way of managing shale development by constantly searching for better plans, designs and processes. Power said, "We're doing our best to fully use today's technology and develop new technologies for the future." ■



At the solar installation site in Questa, New Mexico, concentrating photovoltaic panels with Fresnel lenses move to track the sun.



'Because there is local demand for sustainable energy, we think Chevron's
Questa Solar Project is an important demonstration that
integrates an emerging technology into a community.'

– Luis Reyes, CEO, Kit Carson Electric Cooperative

The Sun Shines on Questa

Chevron transforms the site of a mine in
New Mexico into a 20-acre solar installation

PHOTO: PAUL S. HOWELL



With 10 different companies and 80 workers onsite during construction on 20 acres (8.2 ha), the project team worked more than 40,000 hours without a safety incident.

In the scenic mountains just north of Taos, New Mexico, lies a small village of roughly 2,000 people. Questa, as it is known, has been home to Chevron's molybdenum mine for nearly a century. And with almost 300 sunny days per year, it is now also home to one of the largest concentrating photovoltaic (CPV) solar installations in the United States.

The Questa solar installation fits with the company's vision to make use of existing assets and explore technologies that help the company operate more efficiently. The project also is aligned with the U.S. Environmental Protection Agency's Repower America program, which, among other things, invests in updating the electricity grid to make renewable energy an option throughout the United States.

Collective Expertise

Operations from different areas of the company collaborated to create this installation. Chevron Technology Ventures (CTV), working with Chevron Mining Inc. (CMI), Chevron Environmental Management Co. and Chevron Energy

Solutions, built a demonstration plant as a beneficial reuse of mine property to test this emerging solar energy technology. The demonstration project is enabling Chevron to gain an in-depth understanding of CPV technology and its operational benefits, and to determine whether the technology can be applied to other sites.

Covering approximately 20 acres (8.2 ha) are 173 solar trackers, each about 18 by 21 feet (5.5 by 6.4 m) in size. The installation generates 1 megawatt of electricity that is then sold to a local power cooperative under a power purchase agreement. The electricity is being distributed to homes throughout Questa and other parts of northern New Mexico.

"CTV is demonstrating and integrating these types of technologies to find out how we can help our core operations run more efficiently and in a more environmentally sustainable manner," said Des King, president of CTV.

The Questa installation uses Fresnel lenses to focus sunlight onto three-layer solar cells. The technology is anticipated to be twice as efficient as traditional solar panels while using less photovoltaic material. If successful, this technology has the potential to significantly increase the amount of energy that solar panels can generate.

A Safe, Successful Partnership

Since this was Chevron's first CPV project, collaboration across different organizations was a key factor for success. The CTV team worked closely with a team from CMI throughout the project.

"CMI was instrumental in making this project move along seamlessly—and without incident. They contributed site-specific knowledge; assisted us with safety procedures and site audits; and allowed us to use their material receiving services, specialized equipment and existing contracts with local service providers," said Kent DeBoer, CTV project manager. "We couldn't have done this without them."

Witness Bright Innovation



Chevron is using solar energy to help power the community in Questa, New Mexico, and its own operations in Coalinga, California.

▶ Watch a video of the Questa site at Chevron.com/Next/Questa.

▶ See how Chevron creates steam for its oil field operations in Coalinga, California, at Chevron.com/Next/SolarToSteam.



Working on a solar energy project was a unique experience for Chevron's mining group, making a focus on safety all the more important.

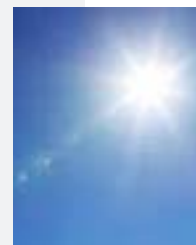
"All involved were serious about safely accomplishing the project goals by identifying potential hazards and communicating any issues," said Steve Mills, safety coordinator for CMI.

With 10 different companies and approximately 80 workers onsite during the construction phase, safety concerns were especially complex. Despite the potential hazards, during the project the project team successfully worked more than 40,000 hours without a safety incident.

Community Benefits

The village of Questa has also seen economic benefits from the project. Chevron worked with several local companies, adding close to \$3 million to the local economy and an additional \$2.5 million with other contractors in the New Mexico area—a significant impact to such a small community. ■

How CPV Works



1 Direct sunlight

Concentrating photovoltaic (CPV) technology works best in areas with high-intensity, direct sunlight.



2 Fresnel lenses

Sunlight is captured by Fresnel lenses, lenses with concentric grooves that concentrate and focus sunlight onto a photovoltaic cell.



3 Solar cells

A high-efficiency, three-layer solar cell captures different wavelengths of the solar spectrum in each layer. These types of cells convert more sunlight to electricity than cells used in conventional solar photovoltaic technologies.



4 Tracking devices

CPV technology requires tracking of the sun. Like sunflowers, the trackers face east in the morning and follow the sun's path throughout the day.

Questa Quantified

Covering approximately **20 acres (8.2 ha)** are **173 solar trackers**, each about **18 by 21 feet (5.5 by 6.4 m)** in size.

The installation **generates 1 megawatt of electricity** that is then sold to a local power cooperative under a power purchase agreement.

Each solar tracker is approximately 18 by 21 feet (5.5 by 6.4 m).





Downstream Technology Vice President Ashok Krishna is in Chevron's Richmond Technology Center with three members of his research team, (from left) Angela Edmond, Sean Solberg and Yalin Hao. Opposite page: Lab technician in the Yeosu Refinery, South Korea.

Making Connections

Downstream Technology isn't just for Downstream anymore

Ashok Krishna, vice president of Downstream Technology, discusses how his group stays on the cutting edge of technology developments to improve the value of Chevron's assets.

Next*: What is Downstream Technology's role within Chevron?

Krishna: Chevron's Downstream & Chemicals business includes the manufacturing, marketing and distribution of fuels, finished lubricants, base oils, chemicals, and fuel and lubricant additives, as well as crude and product supply and trading. This is a wide range of business activity that spans North, Central and South America; Asia; Africa; and Europe.

Our main job in Downstream Technology is, in short, to connect technology innovation

and technical expertise with business needs and opportunities. We partner with other technology groups within Chevron, as well as third-party technology companies, to identify developments of interest to Downstream & Chemicals. Then we help scale up projects, find applications and deploy technologies commercially within our operations.

Next*: Chevron is known for developing hydroprocessing technology. Does this technology still play a significant role in refining?

Krishna: Yes. Hydroprocessing—a process that converts heavy oil into lighter products—is a core competency of ours. We have one of the highest ratios of hydroprocessing to crude capacity of any major refiner

in the world, so we put a lot of emphasis on this particular technology area.

Hydroprocessing has the flexibility to make jet fuel, gasoline or diesel fuel. It's the technology that's used to make premium lubricant base oils. It's also the technology that upgrades liquids produced from natural gas, as in our Escravos gas-to-liquids project in Nigeria. And finally, it's the technology that Chevron Upstream's operations—exploration and production—can use to upgrade very heavy crudes, tar sands and bitumen to lighter, synthetic crudes. We are the world leader in this area, and we've been licensing hydroprocessing technology—ISOCRACKING™, ISOTREATING™, ISODEWAXING™—for more than 50 years. Over the past decade, Chevron's state-of-the-art hydroprocessing

catalysts, novel reactor-internals technology and innovative designs have delivered superior performance for Chevron and its licensees.

Next*: How does hydroprocessing figure into future growth?

Krishna: A couple of decades ago, all the finished lubricants on the market consisted of Group 1 base oils, which were relatively higher in sulfur, higher in aromatic content and less suitable for the higher-efficiency engines being developed. In the '80s and '90s, we developed technology that uses hydroprocessing to make premium base oils, or Groups 2 and 3 oils, which modern vehicles' more advanced engines need. As engines have become more efficient, the North America base oils market has shifted about 45 percent from Group 1 to Group 2 and beyond. We use hydroprocessing technology in our Richmond, California, refinery and in the joint-venture GS Caltex refinery in Korea. When our Pascagoula, Mississippi, expansion project is completed, expected in 2013, Chevron is forecast to become the largest producer of premium base oil in the world.

Next*: You mentioned that you also work with third-party technology companies. What role do they play in technology for Downstream & Chemicals?

Krishna: We've had two joint ventures for a decade. One, Chevron Lummus Global LLC, licenses hydroprocessing technology around the world. In Advanced Refining Technologies, we are joint-venture partners with Grace Davison, a world-class catalyst manufacturing company that supplies most of Chevron's hydrotreating catalyst needs.

These two joint ventures conduct cutting-edge R&D in hydroprocessing technology, while the fundamental catalysis research is performed by Chevron Energy Technology Co. scientists.

As an operator of units based on our own technology, Chevron also shares decades of experience in safe operations of high pressure hydroprocessing plants.

Next*: What role does your group play in project development?

Krishna: We collaborate with Downstream & Chemicals' strategy and commercial integration groups to make sure that all the projects we develop make good business sense; we focus on the most creative technologies that we can implement.

We also have a team of senior experts who contribute to Downstream & Chemicals' bottom line in two important ways: First, they make sure that the most innovative and cost-effective solutions and technologies are being applied in our capital projects, resulting in high capital efficiency. Second, our experts work with plant engineers and manufacturing process experts to squeeze additional value out of existing plants and operations.

Next*: How do you make sure that Chevron's products are top tier?

Krishna: We have a fuels technology organization, with experts who understand fuel chemistry and performance. We are equipped with world-class analytical and performance testing facilities. This enables us to make sure that our Techron®-containing fuels are highest in performance.

Next*: Is Downstream Technology integrated with Upstream in any way?

Krishna: We are now building facilities at Upstream upgrader production sites that look more and more like refineries because the crudes are getting increasingly heavier and tougher to process. Rather than putting billions of dollars into building the refineries for processing those crudes, an option is for crudes to be upgraded at the production site.

In Canada, the Athabasca Oil Sands Project uses our LC-FINING technology to upgrade bitumen from tar sands. In Venezuela, we're looking at converting very heavy crude oil into a lighter, synthetic crude. In Nigeria, we are investing in the Escravos gas-to-liquids plant to convert gas into a waxy, difficult-to-transport liquid, and then use our ISOCRACKING technology to convert it into gasoline and diesel fuel.

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

Krishna: We'll remain focused on developing and deploying Chevron technology that enables superior performance. Our approach to technology is differentiating Chevron through lower costs, higher value, improved efficiency and better products for consumers. ■



Leading the Way

Chevron is gliding ahead in premium base oil production



Chevron is expected to double its premium base oil production after construction is completed on this new manufacturing facility in Pascagoula, Mississippi.

PHOTO: ANTOYA KYLES

Building on decades of technological advances, Chevron is scheduled to become the world's largest producer of premium base oil when its new base oil manufacturing facility is completed by year-end 2013 at the Pascagoula, Mississippi, refinery. The new facility is expected to enable the company to meet the growing demand for premium base oil, which higher-performance engines need. Base oils are the building blocks used to manufacture lubricants, such as motor oil, for consumer and commercial uses.

The key technology involved in the company's base oil production is ISODEWAXING™ technology, which Chevron invented and began using commercially in 1993. This technology enables the removal of essentially all undesirable sulfur and nitrogen molecules and transforms the waxy molecules into high-quality base oil. It also reduces the pour point, the lowest temperature at which a lubricant can flow. As a result, the ISODEWAXING catalytic process significantly increases the yield of lubricant base oil over solvent dewaxing—the conventional method for base oil dewaxing at the time ISODEWAXING was invented.

This technology represented an advance by combining three steps in base oil production—hydrocracking, catalytic dewaxing and hydrofinishing.

Hydrocracking applies high temperatures to remove most of the sulfur and nitrogen. Catalytic dewaxing removes wax molecules. And hydrofinishing uses sophisticated catalysts to convert the remaining impurities to stable base oil molecules.

By combining the all-hydroprocessing route and replacing the catalytic dewaxing step with ISODEWAXING technology, Chevron also lowered capital and operating costs.

Since the initial invention in 1993, Chevron has commercialized seven more dewaxing catalysts with improved yield and product quality. Further, the company is a world leader in hydrofinishing and has commercialized four generations of hydrofinishing catalysts to improve base oil color and stability.

"This technology took a different path than solvent processing. Solvent processing inefficiently removes the poor-performing molecules; hydroprocessing converts those same molecules into premium-quality base oils," said Doug Bea,

2/3

About two-thirds of the world's premium base oil is manufactured with Chevron's ISODEWAXING technology



The Pascagoula Refinery in Mississippi is the site of Chevron's new manufacturing facility for premium base oils, which are the building blocks for lubricants such as motor oil.

Pascagoula Base Oil Project commercial manager. "It makes a much cleaner oil that looks like water, unlike the old technology that produces an amber or honey-colored oil."

"The ISODEWAXING process allows us to significantly increase the production of premium base oil products, gives us greater flexibility with crude feedstocks, and gives the consumer higher fuel efficiency and lower emissions," said Barbara Burger, vice president of Supply Chain and Base Oil.

About two-thirds of the world's premium base oil is manufactured with Chevron's ISODEWAXING technology, and the proportion of premium base oils is expected to grow as new, all-hydroprocessing plants come on line. Chevron and its joint venture Chevron Lummus Global have licensed the technology to more than 15 base oil plants.

Until now, Chevron's base oil production has been concentrated in the Richmond plant and in the supply from Chevron's GS Caltex joint venture in Yeosu, Korea. The Pascagoula project is intended to roughly double Chevron's premium base oil production, serving markets in North America, Latin America and Europe.

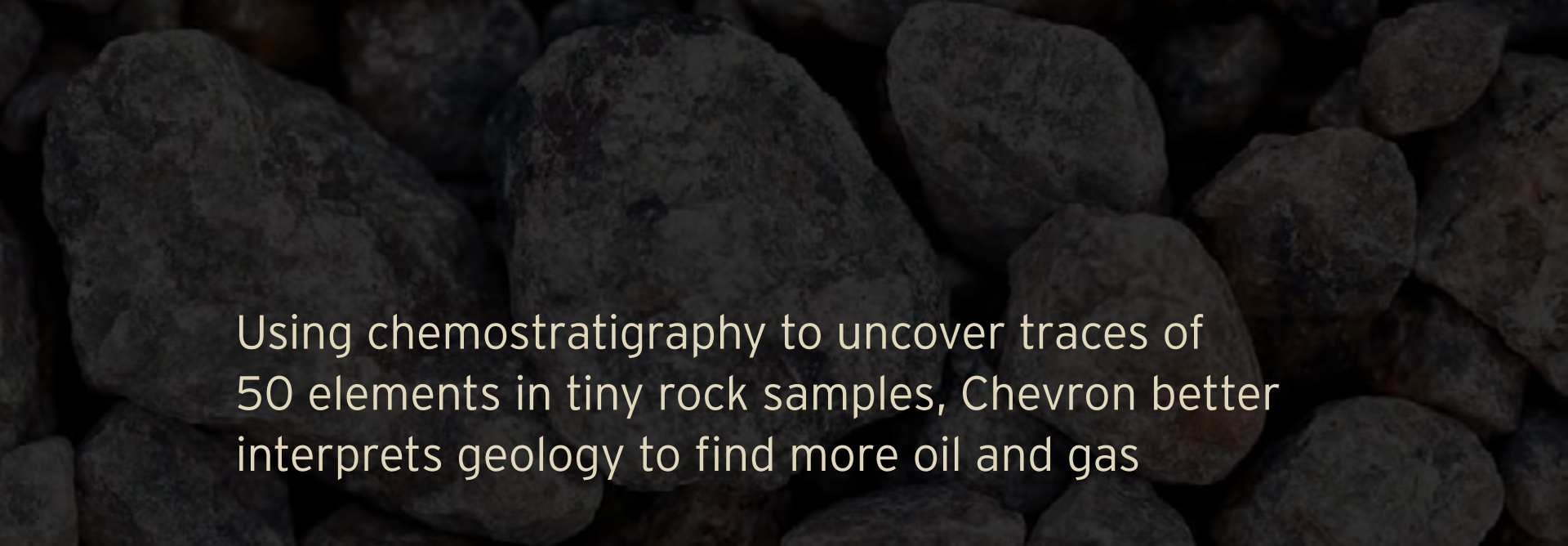
"The project will benefit both the company and the community," said Patti Leigh, general manager of Base Oil. "The project will help us expand our business and provide an enormous boost for the local economy by generating about 1,000 jobs during its construction phase." ■




Securing New

Energy With

Chemical
Fingerprinting



Using chemostratigraphy to uncover traces of 50 elements in tiny rock samples, Chevron better interprets geology to find more oil and gas



The northwest coast of Australia is home to Chevron's Wheatstone Project, which will process natural gas from fields offshore Western Australia.

Exploring the globe for natural gas and crude oil, geologists have long relied on seismic waves and fossils for clues. Now, Chevron's earth detectives are also reading the rocks with chemical fingerprinting to help ensure that major new projects in Australia and the Middle East produce as much energy as possible.

"Rocks are made of minerals, and minerals are made of elements," explained Paul Montgomery, a Chevron geologist and expert in chemostratigraphy, which uses laser mass spectrometry to scan tiny rock samples for traces of 50 elements—lithium, argon, iridium, xenon and others. "It helps us correlate oil and gas reservoirs across

hundreds of kilometers," he said. "We can better understand what we might find when drilling in any direction and how the reservoirs will behave and express themselves."

When integrated with other techniques for interpreting the subsurface, chemostratigraphy is an especially valued tool for understanding the disjointed stacks of gas-rich sandstones discovered by Chevron in the mighty Mungaroo Formation beneath the Indian Ocean off northwestern Australia. Tapping this resource, the Chevron-led Gorgon and Wheatstone projects are expected to provide future supplies of liquefied natural gas to help meet fast-rising Asia-Pacific demand for cleaner energy.



Sandstone and shale cores from the Mungaroo Formation beneath the Australian North West Shelf, such as the Orthrus-2 core section seen below, help reveal the location and characterization of oil and gas reservoirs.



Much more than elsewhere, Chevron needs chemostratigraphy to optimize Gorgon and Wheatstone, two of Australia's largest-ever industrial projects, forecast to cost \$66 billion. Because for all its potential, "the complex Mungaroo Formation lacks good fossil markers. Geologic correlation here is like trying to picture an entire castle from a single room," said Montgomery.

"Also, seismic surveys yield imperfect information on how the reservoirs are connected. Chemostratigraphic techniques can greatly enhance our understanding," said Montgomery. "It's absolutely critical to the long-term performance of these deepwater gas fields that we drill just the right number of very large wells at precise locations and depths. We need these wells to run great for 30 years."

Chemostratigraphy also provided new insights on the mammoth First Eocene oil reservoir at Wafra in the Partitioned Zone between Saudi Arabia and Kuwait, where Chevron is targeting 6 billion barrels of potentially recoverable oil with steam-injection technology. Chemical fingerprinting helped confirm a geologic profile built from alternative data, demonstrating that chemostratigraphy, coupled with other techniques, can provide the detailed stratigraphic correlation needed for a successful Wafra steamflood.

In the United States and Eastern Europe, chemostratigraphy will help Chevron develop new supplies of gas from shale, which is difficult to analyze using fossils. Oil and gas projects in Angola, the U.K. Atlantic Margin and other locations have also benefited, said Montgomery. "Everywhere we've used this technology, it has added to our success."

Mapping geology with mineral clues such as color isn't new, but in the past decade, better, faster spectrometry has made chemostratigraphy a more accessible and affordable tool, said Montgomery. Still, the surveys require months of work on drilling rigs, in laboratories and in technical centers where geoscientists interpret the mineral DNA.

A recent, major survey for Gorgon, for example, collected and scanned some 1,500 samples from eight wells—a total of 75,000 element profiles. Chemostrat Ltd. analyzed the samples for Chevron by sampling tiny rock cuttings brought up from different depths during drilling.

Technicians painstakingly labeled, sorted, washed, crushed and heated the samples for the laser spectrometer, which measures light wavelengths to reveal the varied chemical personalities of different rock layers. The result: nine chemostratigraphic packages, 22 geochemical units and 19 sand units to help Chevron geoscientists map 30 million years of depositional history from prehistoric rivers during the Triassic Period, about 200 million years ago.

In this lost world, sand, silt and organic matter accumulated in channels and deltas across a steamy, sprawling landscape now buried thousands of meters beneath the ocean floor. Shales leaked hydrocarbons into the Mungaroo's sandstone sandwich, and huge blocks slid up and down, creating a formidable puzzle of fault blocks and pinched-out layers.

Fortunately, Mother Nature left her chemical fingerprints to help Chevron best develop a vast storehouse of Australian gas—and no doubt, many other energy treasures ahead. ■



Australia Update

Wheatstone's neighbor Gorgon is a powerhouse of activity and development.

For updates on Wheatstone and Gorgon, visit ChevronAustralia.com.



'The complex Mungaroo Formation lacks good fossil markers. Geologic correlation here is like trying to picture an entire castle from within a single room.' – Paul Montgomery, Chevron geologist



PHOTOS: TOP, MIKE EDMONDSON; BOTTOM, ROBERT GARVEY/8KAY DESIGN

Marine biologists, such as Anthony Bougher, seen here, conduct intertidal surveys in the Indian Ocean adjacent to the site of Chevron's Wheatstone Project.



Chevron seismic specialist Sarah Cooke sees the potential of using ocean-bottom nodes (like the one shown) to collect data.

Far off the steaming coast of West Africa, nearly a mile (1.6 km) down in the Gulf of Guinea, a boxy, deep-sea vehicle cradling a 100-pound (45.4-kg) node stuffed with instruments hums through the blackness.

The remotely operated vehicle (ROV) safely avoids the huge processing facility, seafloor wells, flow-line tentacles and other equipment at the Agbami Field, a Chevron-operated technological titan capable of producing 250,000 barrels of oil per day.

The ROV places the node on the bottom and deftly plugs the unit's package of listening devices into the seabed. Hundreds more follow, 984 to 1,312 feet (300-400 m) apart, forming a vast grid to record two months or more of seismic-reflection data. Then one by one, the nodes are retrieved and brought to the surface to download their data.

Logistically challenging but rich with potential, ocean-bottom-node (OBN) surveys are helping Chevron better understand its oil and natural gas reservoirs—especially the complex and hardest-to-map formations in deep water. OBNs hold promise for

PHOTO: PAUL S. HOWELL

VIEW FROM THE BOTTOM

Four-dimensional seismic surveys with ocean-bottom nodes are sharpening Chevron's view of remote, deepwater oil and gas resources, revealing how reservoirs change during production

improving four-dimensional, or 4-D, time-lapse seismic surveys.

"This is a really cool technology," said Sarah Cooke, a seismic specialist with Chevron in Houston. "The improved 4-D shows us how fluids move within the rock and reveals oil and gas we've missed. And watching how reservoirs change during production will show us where to place future wells."

Cooke sees OBN as a rising star in energy supply security as the world relies more on oil and gas from deepwater fields. Worldwide deepwater output of oil and petroleum liquids roughly tripled in the past decade to about 6 million barrels per day and could reach 10 million barrels by 2020, about 10 percent of world supply, according to Wood Mackenzie, an energy research and consulting company. Chevron, with partners, explores and operates in deep water in nearly a dozen countries, with billions of dollars in new projects planned or under construction.

Teaming with SeaBird Exploration, Chevron has also used OBN to better delineate the Rosebank oil discovery in

the remote Atlantic Margin of the United Kingdom. Knowing the deepwater field's precise anatomy beneath layers of volcanic basalt—which strongly attenuates most seismic frequencies—is key to deciding how best to develop Rosebank, which may begin its front-end engineering design in late 2012.

For Agbami in 2010, SeaBird used 660 nodes at more than 1,500 points across 370 square miles (600 sq km) of ocean bottom in the world's largest OBN survey. In 2013, the nodes should be back, providing a fresh picture to help optimize Agbami's development.

"The Agbami job brought Chevron to the forefront in the field of global OBN surveying," said Ken Sample, director of Deepwater Assets and Production Sharing Contracts.

Of course, oil companies since the early 20th century have been bouncing sound off the earth's crust to pinpoint targets for exploratory drilling. Later, geoscientists began using seismic data to better map discovered reservoirs. OBNs may raise seismic to a new level with safer operations, better image detail and improved 4-D repeatability, said Cooke.

Nodes can be safely placed next to production facilities, removing the hazard of towing long streamers holding thousands of seismic sensors through busy areas. Stable, closer to the reservoir and unfazed by currents and water noise, nodes also greatly enhance all-azimuth and wide-azimuth surveys, shot to reveal areas of oil and gas beneath salt domes, basalt and other geologic barriers, said Cooke. "OBN lets us do in deep water what we previously could do only on land."

But it's the repeatability factor that Cooke finds most promising. Four-D requires a baseline survey, then an identical monitor survey a couple of years later. It's virtually impossible to perfectly repeat source and receiver geometry in a towed-streamer survey, but OBN monitor surveys can place nodes in almost exactly the same spots as baseline grids, thereby achieving receiver repeatability. The resulting gains in precision and clarity are already helping the world make the most of its deepwater energy resources. ■

Land of the Sun

Chevron invests in research in Qatar to find region-specific solar technologies and improve energy efficiency



Summer in Qatar:
Temperatures can reach
as high as 135 degrees
Fahrenheit (57° C).

PHOTO: GETTY IMAGES

Solar energy is both elegantly simple and fiendishly complex. On the surface it looks as easy as placing photovoltaic (PV) panels in the sun, wiring them up and enjoying endless electricity. But in reality it takes highly trained experts to design and build solar systems, and there are hundreds of technologies and products from which to choose.

In addition, a PV panel's efficiency is influenced by the local climate. Even modest solar power plants can cost tens of millions of dollars, so planners must be certain that a panel will perform well in real-world conditions.

This is especially important in the Middle East. Most PV panels are designed and installed in places with mild climates, such as Europe, Japan and the United States. But in countries like Qatar, where summer temperatures regularly exceed 110 degrees Fahrenheit (43° C) and can reach as high as 135 degrees (57° C), there is scant rain to wash off the dust from the panels, and counterintuitively, PV cells actually perform worse as they get hotter.

As part of Chevron's five-year commitment to the Qatar Science & Technology Park (QSTP), the company is investing \$10 million in the Center for Sustainable Energy Efficiency (CSEE), which opened in March 2011. Chevron also is establishing a solar test facility at QSTP in collaboration with GreenGulf Inc., a Qatari clean technology and renewable energy company. The \$20 million facility, in which Chevron and GreenGulf



At Chevron's Center for Sustainable Energy Efficiency in Qatar, Abdalla Al-Qatami (left) and Chevron energy engineer Amer Al-Rayahi explore an interactive exhibit: the color mixer. The mixer demonstrates the results in the color spectrum of the different temperatures of light, shown as combinations of red, green and blue. The intersection of these colors creates new secondary colors, while the combination of all three creates white.

A Solar System for Qatar

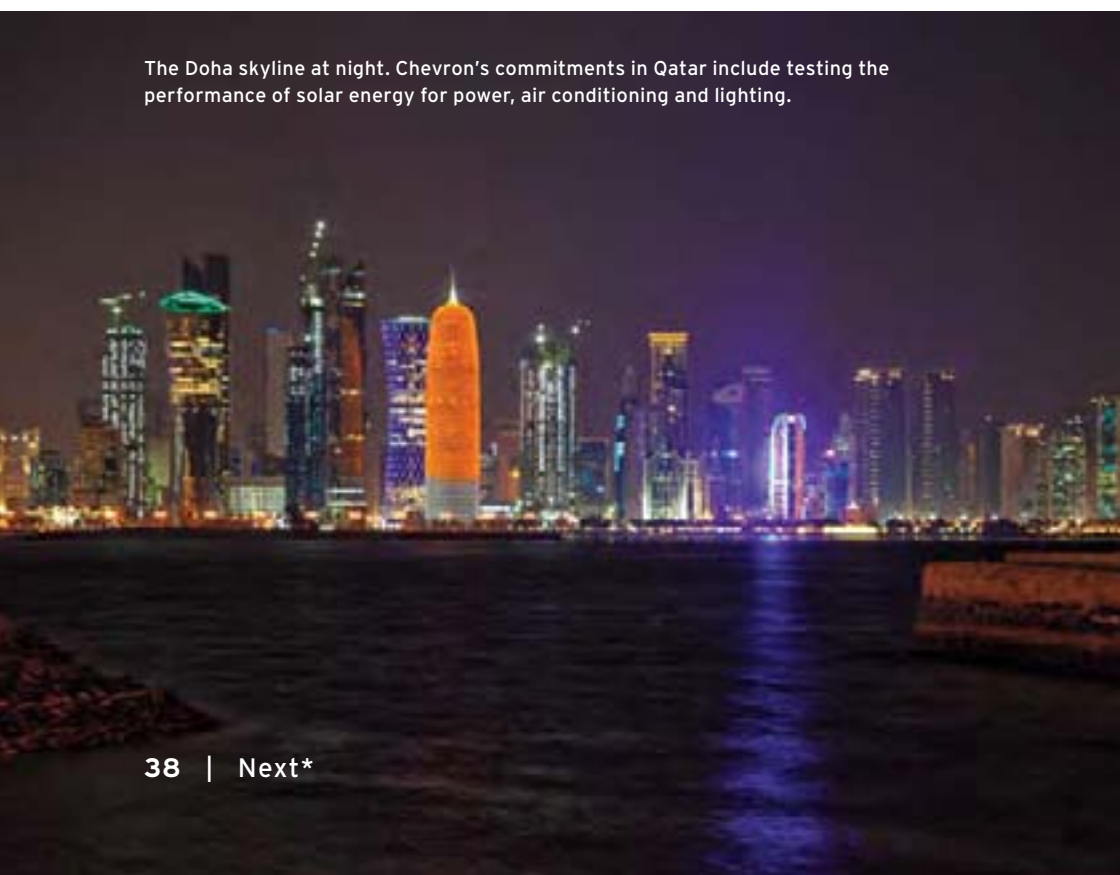


Qatar's climate presents special challenges for solar panels, but Chevron and its partners are testing ways to improve performance.

▶ Explore Qatar and Chevron's projects in the country at Chevron.com/Next/CSEE.



Chevron solar construction project manager Jeff Muñoz (left) and energy engineer Amer Al-Rayahi study the newly installed solar panels at the Qatar Science & Technology Park. The 9-acre (3.5-ha) solar installation is a collaboration between Chevron and GreenGulf Inc., a Qatari clean technology and renewable energy company.



The Doha skyline at night. Chevron's commitments in Qatar include testing the performance of solar energy for power, air conditioning and lighting.

are investing up to \$10 million each, is planned on a 9-acre (3.5-ha) site equipped to test dozens of solar technologies from all over the world.

The technologies being studied include photovoltaic solar, by which semiconductors convert sunlight directly to electricity, and concentrated solar and solar thermal, which capture and use the heat of the sun's rays.

The results of the tests here can help determine the most appropriate solar technologies for the region.

Tidu Maini, Ph.D., executive chairman of QSTP, said that environmental factors, such as high humidity, high heat and excessive dust, are the main challenges that affect performance. For example, dust accumulated on photovoltaic panels after six months in the Middle East can reduce their effectiveness by 40 percent.

In addition to solar power, Chevron expects to identify commercially available and near-to-market technologies in solar air conditioning, solar desalination and energy-efficient lighting that work well in the region's desert climate.

In Qatar, air conditioning can account for more than 60 percent of electricity use. Solar could be used at peak times in summer when the energy load for air conditioning is highest. At QSTP, Chevron plans to operate and study a state-of-the-art solar air conditioning system that uses the sun's heat rather than electricity to drive a refrigeration cycle.

Guiding these activities is Chevron Energy Solutions, among the largest installers of solar energy and energy efficiency solutions for school districts, universities and other public sector institutions in the United States. Through its technology development partnerships, Chevron Energy Solutions is at the forefront of energy-efficient lighting technology and its commercialization, and the company stands out for its unique ability to deliver comprehensive, economic solutions that provide long-term savings for its customers. Company experts have been working onsite at the CSEE, lending their extensive knowledge of solar and efficiency systems to help establish the new facilities in Qatar.



Amer Al-Rayahi and Jeff Muñoz observe a solar panel showing the effects of solar angles that are created by such conditions as time of day and seasonality on energy output.

“The test facility in Qatar is an exciting opportunity to apply the broad and deep understanding of solar energy that our company is known for in the United States,” said Chevron Energy Solutions President Jim Davis. “Our experience in engineering and building solar systems gives us a distinct advantage in completing the QSTP project.”

Carl Atallah, Chevron’s country manager in Qatar, said, “The solar test facility in Qatar complements similar Chevron facilities in California and New Mexico, providing us with the opportunity to test the performance of various solar technologies in widely different environments. We are proud to take a lead technical role in this study on sustainable energy.” ■

The Energy Efficiency Experience

A highlight of Chevron’s Center for Sustainable Energy Efficiency (CSEE) at the Qatar Science & Technology Park is the visitors’ center, where guests, through interactive displays, can learn about and experience next-generation lighting, solar technologies and energy efficiency.

Along with the goal of identifying solar power, solar air conditioning and low-energy lighting technologies best suited for Qatar’s climate, the Chevron CSEE conducts seminars and workshops on sustainable energy designed for a variety of audiences, including industry professionals, researchers and students, and the general public.

Students and the public can visit the education center to learn about solar power and ways to reduce energy consumption. Engineering students are receiving training and internships. And municipal planners, property developers, engineers and architects can obtain detailed information on the performance of solar and efficiency technologies and consider implementing these green building technologies in their construction.



Chevron's summer intern program for students in technology-related fields is a two-way street. The students gain access to seasoned, knowledgeable mentors and supervisors; real-world experience; networking opportunities; and often, at the end of the internship, a job offer. Chevron, in turn, gains exposure to talented young people with backgrounds currently in great demand, such as petroleum engineering and earth science.

And there's more. "These young interns often come up with fresh ideas and perspectives that impress our senior people and spread through our enterprise," said Tiffani Vashaw, with Chevron Human Resources.

Most of the interns are assigned to specific projects that give them an opportunity to "get their hands dirty while working at a well site or drill rig or other facility," Vashaw continued.

Wherever the interns are assigned, most of them complete their internships by presenting well-considered, detailed reports. Doug Holden, a Chevron organizational change advisor, provided examples. "Last year, a petroleum engineering intern did reservoir modeling of a quality that is typically seen coming only from employees with three to four years' experience," he said, "and an earth science intern impressed everyone by doing the complete subsurface mapping of a field in our Appalachian/Michigan operations."

This hands-on experience is a distinguishing feature of the Chevron intern program.



Hands-On Experience for Summer Interns

Chevron's internship program broadens access to talented students in technology fields

Another important ingredient: collaboration. "That goes back to our culture—and it's an aspect the interns appreciate," said Holden.

That sentiment recurs in conversations with current interns. "The main benefit of this program is that I can learn a lot from my mentor and co-workers," said Qi Ren, a Chinese Ph.D. student in geophysics at the University of Texas. "This internship will give me a cue about the direction of my own research on campus."

Le'Kendra Fusilier, who is majoring in petroleum engineering at Louisiana State University, is focusing her internship on learning to become a digital engineer. "It combines information technology with oil and gas disciplines," she said, "and it's going to be extremely beneficial in coming years because everything is turning much more technical."

Sydney Bowles, a student of geology at Louisiana State University who did her field work in New Zealand, is learning new things—such as interpreting well logs and evaluating fields—that are giving her "firsthand experience of what it will be like to work full time in the industry."

And Ernesto Valbuena, a Venezuelan Ph.D. candidate at Texas A&M University, is working on software packages that "will provide more knowledge about the most efficient ways to apply our technology in reservoir simulators and surface network integration."

In addition to providing the interns with a rich experience and adding value to the business, these internships enable the students to evaluate Chevron, and to be evaluated as potential future employees. Based on the high rate of job offers that have grown out of the program, the process is working well. ■



Top left: Sydney Bowles, a geology intern, observes a nuclear energy display at the Houston Museum of Natural Science in Texas. Top right: Le'Kendra Fusilier, who is majoring in petroleum engineering, works on the integration of information technology with oil and gas disciplines. Left: Ph.D. candidates Ernesto Valbuena and Chukwudi Chukwudozie, who work on reservoir simulation models, attend a program for interns at the Houston Museum of Natural Science.

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Crossing the Canyon

Chevron solves a technical challenge to move natural gas from Angola under the Congo River

With vital right-of-way permits approved by the Democratic Republic of the Congo, Chevron is moving ahead on its Congo River Crossing Pipeline project to bring gas from Angola Blocks O and 14 to ALNG, Angola's first liquefied natural gas plant. The offshore and onshore pipeline will be approximately 87 miles (140 km) long and is designed to transport up to 250 million cubic feet per day of natural gas.

The most technically challenging aspect of the project is crossing the Congo River Canyon. This submarine canyon, the world's largest, was carved into the seabed by the Congo River, which discharges into the Atlantic Ocean. The canyon extends 470 miles (760 km) out to sea.

To cross the canyon, two wellbores will be drilled simultaneously from shallow water platforms located on each side of the canyon. The wellbores will transition from vertical to horizontal, and will intersect almost midway beneath the canyon, where the maximum water depth at the crossing is one-half mile (0.8 km) and the intersection approximately 2,000 feet (610 m) beneath that.

An additional challenge for the project team will be to successfully install the two platforms in an area just offshore of the Congo River, where currents routinely run approximately 6 knots.



PHOTO: GETTY IMAGES