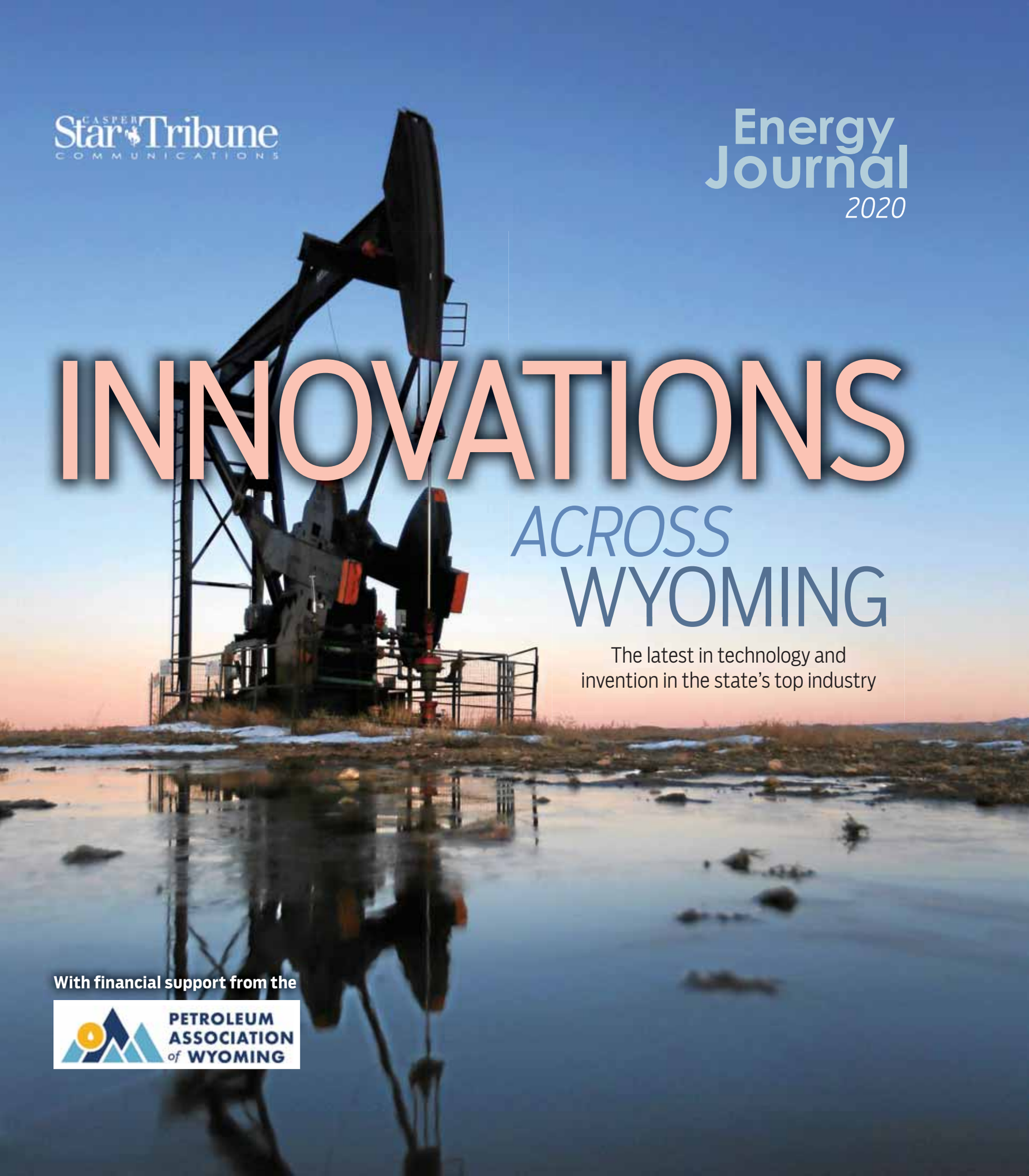

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Energy Journal 2020

INNOVATIONS *ACROSS* WYOMING

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Facing our challenges HEAD ON

Welcome to the Star-Tribune's 2020 Energy Journal

CAMILLE ERICKSON
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It's easy for me to feel like the stories I publish each day on energy and natural resources in Wyoming are full of doom and gloom: declining coal demand, bankruptcies, layoffs, budget shortfalls, environmental contamination. The slew of coal company bankruptcies last summer plunged hundreds of families in the dark. Firms caught flat-footed by coal's tumbling demand left counties high and dry with painful budget shortfalls.

What's more, natural gas providers, strapped by difficult market conditions, have had little choice but to shut in wells in communities deeply dependent on mineral production revenue. Oil prices have been stubbornly low from growing geopolitical unrest and the concerning spread of the coronavirus.

In short, there's a lot to worry about. And there's likely not one person in Wyoming who hasn't felt the consequences of these economic shocks.

But as the largest net energy supplier in the country, Wyoming is also playing a critical role in the shaping the future of energy. In fact, there's not one area of energy research and innovation that Wyomingites don't have their hands in.

The Star-Tribune's 2020 Energy Journal investigates the promising technological advancements transforming the energy sector, with a particular look into how our state is charting the course.

Ultimately, I worked to capture a glimpse of hope in each of these innovations, most conceived within the state's borders. I was careful not to glamorize the steep challenges facing the state, or suggest that there's a silver bullet. I know the stakes are high.

But I think it's important to remember that technological changes can allow us to creatively adapt to what often feel like unsolvable problems.

Today, that means confronting the exponential rise in carbon dioxide in the earth's atmosphere and the market-driven transition toward renewable energy.

Wyoming scientists, entrepreneurs and conservationists are responding — finding ways to treat and reuse the trillions of gallons of produced water typically disposed of during oil production, diverting gas from flaring toward energy-intensive activities like data processing and introducing photographic software to ensure land reclaimed after extraction is maintained.

Many people I spoke with admitted that what they're doing to solve today's energy challenges is not enough, but that it's at least a start. Almost all expressed the obligation they felt toward the environment, the state and its people.

Every contributor to this publication exhibited signs of hope and ingenuity, showing a readiness to address what may on its surface appear to be an unsolvable problem head on.

Follow the latest on Wyoming's energy industry at @camillereports

Turning waste into WATER

Industry and ranchers are combining forces to reuse a drilling byproduct

CAYLA NIMMO, STAR-TRIBUNE

Joe Rankin walks on his farm with two dogs in February outside Douglas. Rankin is in the process of securing a deal with Encore Green Environmental to use treated water from oil activity to help irrigate his land.

CAMILLE ERICKSON
307-266-0592, camille.erickson@trib.com

SHAWNEE — That morning, the sky turned white as teeth. The wind grew frigid and furious. The air stayed dry.

Thin shoots of hay poked out from below the sparse coating of snow on JS Rankin Ranches roughly 25 miles outside Douglas. Oil and gas wells and pumps speckled the otherwise blank horizon.

A team composed of two soil scientists, a rancher, a computer programmer and an energy expert visited owner Joe Rankin's cattle ranch with a plan on that brutal day in late February. The group makes up the agricultural midstream company called Encore Green Environmental. They are intent on reusing water from nearby oil and gas production to improve Wyoming's soil, air and vegetation to sequester more carbon.

In this case, Encore has a vision to treat and repurpose the leftover water to irrigate Rankin's land and increase his hay yield.

Encore needs to overcome several hurdles before it can spread a few inches of water onto Rankin's ranch. But the crew arrived on Feb. 25 determined to collect 16 soil samples and learn a bit more about the land.

Out in the field, the agronomists, or soil scientists, used a metal probe to slice the ground's frozen surface. It emerged with a mouthful of soil to take back to a lab for testing. The soil's chemistry will guide the scientists in the coming months as they make plans to supply water to the thirsty land. Encore will then set up a water treatment plan. But that will first require buy-in from Rankin, proximate operators, state regulators and others.

The process may seem tedious, but there's a sense of urgency underlying Encore's ambitions.

For every barrel of oil produced from hydraulic fracturing and horizontal drilling, three to six barrels of water come up with it. Operators often elect to reinject water, known as produced water, back into the ground or into disposal wells. As a result, some 2.4 billion gallons of produced water is created through oil and gas drilling every day in the U.S.

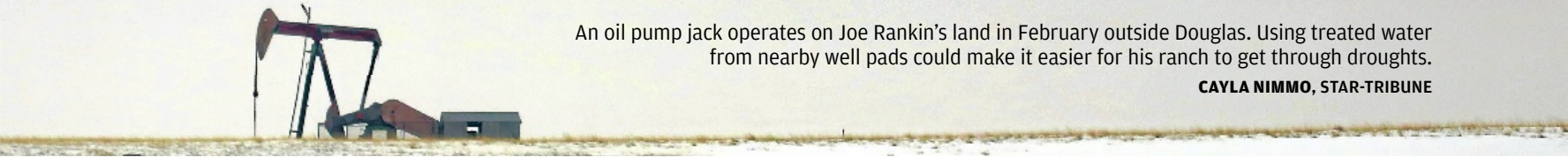
"We are going to run out of water. Look at this," Encore CEO Marvin Nash said in a strained tone as he gazed out onto Rankin's ranch. "This is arid land."

Nash and his wife, Darlene, launched Encore after seeing the need ranchers had for water and the trillions of gallons of produced water jettisoned each day by oil and gas companies. What's more, he expects a growing water crisis in the future, one that could spread like fire throughout the Rocky Mountain Region.

"It is an opportunity, but also an obligation to use this water rather then jamming it back into the ground," Neal Fehringer, the soil scientist, said.

Providing the produced water to nearby landowners for reuse may seem obvious, but it's not a widespread practice. The problem largely comes down to the water's quality. When produced water bubbles up to the surface with oil, it's brackish and no longer clean. It's loaded with salts, minerals, metals, not to mention highly insoluble man-made chemicals needed for fracking. (The minerals and metals build up over years and years in underground formations).

Please see **WATER**, Page 4



An oil pump jack operates on Joe Rankin's land in February outside Douglas. Using treated water from nearby well pads could make it easier for his ranch to get through droughts.

CAYLA NIMMO, STAR-TRIBUNE

Wyoming OIL & GAS CONSERVATION COMMISSION

Since 1951, the Wyoming Oil and Gas Conservation Commission has seen a lot of innovation in the industry. From that day forward our role has been to ensure responsible development and management of Wyoming's oil and gas resources and provide appropriate environmental stewardship for Wyoming's citizens.

This modern photo shows a rig using SimOps, a program that allows a company to perform drilling, completions and producing operations on multiple wells simultaneously on the same pad. This innovation reduces the amount of time typically required to bring a well on line by more than 50 percent and significantly reduces the environmental impacts of drilling.

CAYLA NIMMO, STAR-TRIBUNE

Christian Guenther, right, drives a truck on JS Rankin Ranches property and takes soil samples while Neal Fehringer records the data. Both work for Encore Green Environmental, a company that aims to treat produced water from oil and gas production so it can be used again.

CAYLA NIMMO, STAR-TRIBUNE

Marvin Nash, CEO of Encore Green, talks about the goals of his company, which include re-purposing produced water from oil and gas drilling for agricultural use. Nash founded the company with his wife, Darlene, after observing that ranchers needed water and trillions of gallons of it were being produced by drilling operations.

Water

From page 2

Under Encore's program, scientists will closely study the water to find the best treatment method for it. Scientists will then test the soil to identify its needs. They keep an eye on how much clay, sand or salinity the soil contains to consider what elements may be needed to improve the soil's health. Before applying water and after treatment, they retest the water.

Along the way, they're working to connect industry to nearby ranchers. The crew is also keeping track of all the data they collect. Seth Frentheway, Encore's technology president, built a database to track the amount of oil and water every well in Wyoming is producing. That way, when they team up with a landowner, they can estimate how much water might be available for irrigation, livestock or other uses.

Back on the ranch

For Rankin, the rancher, more water for irrigation and livestock could have huge returns for his family.

"This will benefit us and, if it works well, it will benefit our relationship with the oil companies," Rankin said.

Around 2013, he endured a sustained drought and almost had to sell his most prized cattle. He was desperate for water, knowing all too well the consequences if it didn't come. Ranchers facing long droughts often have to make one of two choices: purchase expensive hay or reduce the herd in a depressed market to survive. Neither options are ideal, and the financial damage can follow families for years.

"If you hit three to five years of drought all you have is your land, so what do his kids do?" Nash asked. "They can't make a living here. So what starts happening is we start losing an entire element of our society."

Droughts aside, Rankin still has trouble growing a sufficient amount of hay because of his fields' parched conditions. He often purchases thousands of tons of extra hay per year to supplement his own crop.

"It gets a little spendy," he said.

But with additional water and improved soil conditions, he hopes to be able to produce more of his own hay. What's more, once the water is treated, Rankin may also be able to return extra water to his reservoirs and sell it back to oil and gas companies in need of water for drilling.

Please see **WATER,** Page 6

CAYLA NIMMO, STAR-TRIBUNE

Encore Green uses a hydraulic probe mounted inside a truck to take soil samples on the land of JS Rankin Ranches near Douglas.

CAYLA NIMMO, STAR-TRIBUNE

Soil scientist Neal Fehringer points to an aerial map of JS Rankin Ranches where several well pads are located.

CAYLA NIMMO, STAR-TRIBUNE

A team of soil scientists drive to multiple locations on JS Rankin Ranches near Douglas to take soil samples.

Water

From Page 4

Ultimately, the water has restored his hope in passing down the ranch. Rankin has three grandchildren.

"Are any of them going to want to be in this place?" Rankin asked. "I'm working with the assumption that one of them will be there to carry us on. We've been here almost 75 years."

Recycling the produced water for the meadows of hay or pastures of grasses enables a rancher to pass down a business to the next generation, Nash explained. But it also boosts soil health, prevents erosion and relieves pressure on local water supplies, especially if oil and gas operators decide to reuse the treated water for fracking again.

"For me, coming to Joe (Rankin)'s ranch is where this whole thing got very real," Nash said. "I mean, this gentleman is out here trying to make a living and all this water just keeps getting wasted away."

Forever chemicals and skeptics

On the route back toward Douglas from JS Rankin Ranches, soot-coated water trucks whooshed by, dominating the bumpy dirt road. The first time John Robitaille, president of Encore, visited the ranch, he tried to count the number of trucks but lost track.

The trucks carry the briney produced water from the oil and gas sites to disposal wells or open ponds. For operators, transporting water by truck or pipeline can add up quickly and whittle away at profit margin, which can be especially painful during periods of low oil prices.

CAYLA NIMMO, STAR-TRIBUNE

Marvin Nash, CEO of Encore Green Environmental, wears a hat with an oil pump jack on the back as he drives around the land on JS Rankin Ranches near Douglas on Tuesday, Feb. 25.

"I want the general public to question why we're not using this water," Robitaille said. "We have it, we can use it, and we should."

Encore Green's team considers their solution of treating the produced water onsite and repurposing it nearby as a boon for operators too.

Not everyone is as enthusiastic about Encore's idea.

Several conservation groups in the state have concerns about the produced water. Many fear reapplying the water to the land, no matter what treatment processes are used, is too risky. For one, scientists often don't have a full list of every single chemical mixed into fracking water. That makes targeted water treatment not just difficult, but next to impossible. Environmentalists fear the water could breed legacy environmental issues.

Jonathan Brant is a professor and engineer, directing research at the University of Wyoming's Center for Excellence in Produced Water Management. He's studying how to reduce the impact of produced water disposal on the environment. He's also innovating water treatment methods to make them more economical.

But finding a solution for removing all the man-made organics, or chemicals, from produced water is a persistent challenge.

"Man-made organics are very difficult to remove from water, even with our best treatment processes. We don't know if they persist after treatment," Brant explained. "Having that as an unknown is what has hindered (state and federal regulators) from allowing us to reuse this water for a lot of things."

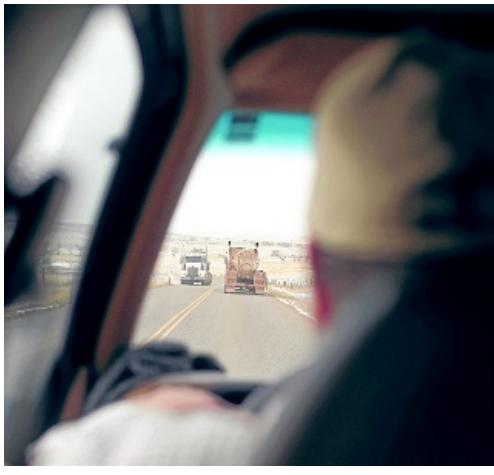
But Brant remains confident in Encore Green's approach to the problem.

"Encore Green is really doing a great job, because they're managing the water coming in and they're going to be managing the water coming out, well before

Please see **WATER,** Page 7

CAYLA NIMMO, STAR-TRIBUNE

Rancher Joe Rankin meets with Encore Green at his home near Douglas. Rankin owns and runs JS Rankin Ranches and is in the process of securing a deal with the company to use produced water that's treated on his land for his own agriculture use.



CAYLA NIMMO, STAR-TRIBUNE

Two trucks hauling water occupy the road in front of the car driven by Marvin Nash, CEO of Encore Green. Nash's company seeks to reduce this type of traffic on rural roads by treating produced water on site so it can be used in nearby agricultural operations.

Water

From page 6

it goes on the ground," the scientist said. "They are managing the development of the soil health over time too, so, they're covering their bases."

Still, Brant thinks its essential for companies handling produced water treatment and reuse to consider any potential long-term impacts to the land.

"You have got to overdo it when you first start so that you don't make a mistake," Brant said.

The team said they've taken a close look at how produced water was reused during Wyoming's coal-bed methane boom about a decade ago and learned from that experience.

"People say there have been a lot of mistakes made, but we learned lessons from coal-bed methane," Fehringer, the soil scientist said. One major change in approach involves how much water scientists will place on the land. Instead of roughly 20 to 30 inches of treated water, they will likely only spread 6 to 8 inches to supplement the rain or snow that comes naturally.

CAYLA NIMMO, STAR-TRIBUNE

An oil pump jack operates on Joe Rankin's land near Douglas Tuesday, Feb. 25. Rankin is in the process of creating a deal with Encore Green Environmental to use treated water from the oil rigs for his own agriculture.

All of what Encore Green is doing comes down to water.

On Jan. 3, Wyoming Department of Environmental Quality granted Encore Green a permit to apply 7,000 gallons of treated water onto the surface of private land near Pine Bluffs.

In the car driving back to Douglas, the team didn't hide its excitement at the latest development. For months, they had worked with several state agencies to build up confidence in their methods and design a permit.

"We have to take baby steps and be very cautious at the beginning and we have to show that we can do it without damage," Robitaille said.

Risks and all, Encore Green considers the opportunity too precious to pass up.

"Water is about livelihood," Nash said. "Everything comes from the water. But there is an obligation to solve this water problem and there's an opportunity to do that. It just takes the work of the energy industry, the rancher farmer and of everybody."

Follow the latest on Wyoming's energy industry at @camillereports

What's in produced water?

Scientists at the Center for Excellence in Produced Water Management are searching for ways to extract additional resources from produced water – from additional hydrocarbons to precious metals and minerals.

Precious Metals

- Lithium, iodine and uranium
- Rare earth elements

Water (2.4 BG/day)

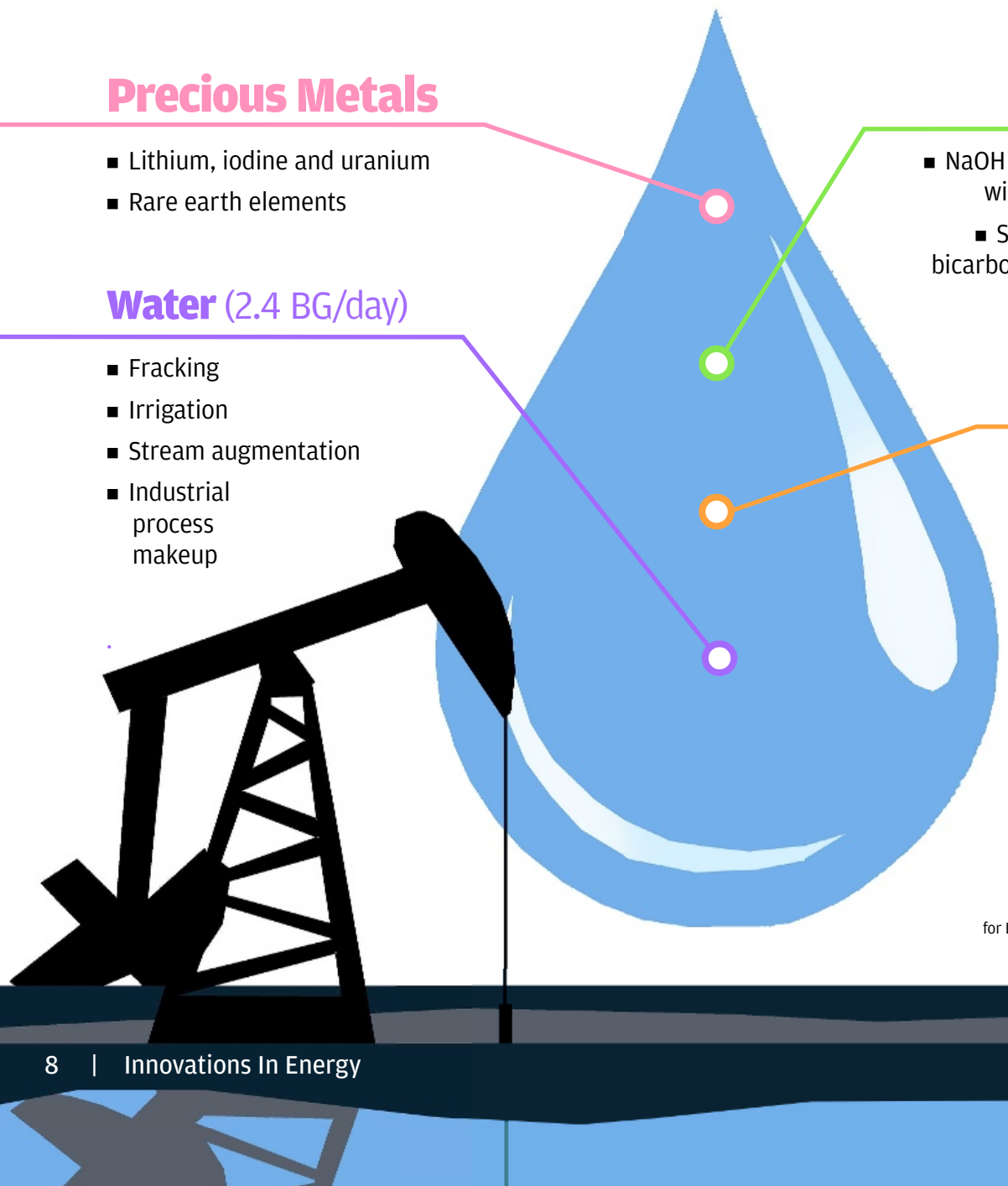
- Fracking
- Irrigation
- Stream augmentation
- Industrial process makeup

Minerals

- NaOH production from NaHCO3 with membrane electrolysis
- Sodium hydroxide, sodium bicarbonate, sodium, potassium, magnesium and calcium

Other

- Hydrocarbon recovery
- Methanol and other additives for reuse
- Energy production (heat and chemical potential)



LEE ENTERPRISES GRAPHIC

Source: University of Wyoming Center for Excellence in Produced Water Management

The unlikely marriage of cryptocurrency and crude

One company is using excess natural gas for computing power

CAMILLE ERICKSON
307-266-0592, camille.erickson@trib.com

The pair hatched their big idea while climbing to the top of Mount Columbia and Mount Harvard in Colorado.

With open skies and endless trails, Cully Cavness and Chase Lochmiller had no shortage of time to talk. And over the course of the 18-hour day, the oil executive and tech wiz — who first met back in high school — combined their brainpower to launch Crusoe Energy Systems. Crusoe is a company determined to help oil and gas operators avoid flaring, or burning natural gas.

Their solution appears simple, but potent: take excess natural gas, convert it to electricity on a well site and then use that power for data computing.

Shale operators often have their eye on liquids over gas. Oil typically fetches a higher profit for companies than its bedfellow, natural gas.

But when operators drill deep, both oil and gas come up. What to do with that excess natural gas can be a pain for operators, especially when well sites sit in remote areas without pipeline infrastructure.

With natural gas prices dipping below $2 MMBtu, that excess gas is at best a byproduct and at worst a nuisance, Cavness said. Flaring offers oil producers a way to rid the site of abundant gas. But flaring's effulgent flames obstruct horizons, contaminate the air and burn up state revenue, according to critics.

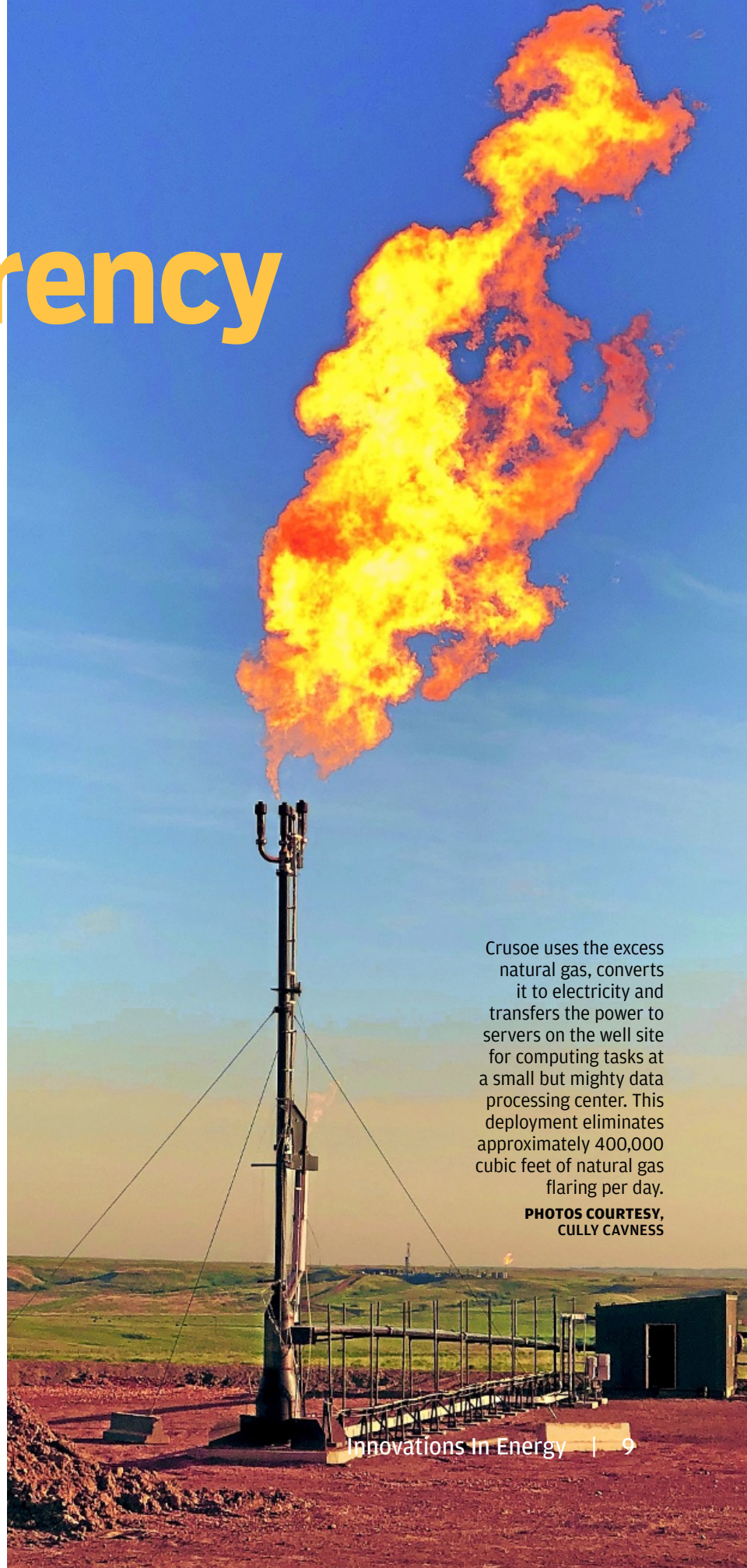
"We try to focus on areas where flaring is a problem and is constraining their operations," Cavness noted.

Instead of wasting natural gas, Crusoe and other new companies have started dreaming up beneficial uses for the gas on site.

Crusoe uses the excess natural gas, converts it to electricity, and transfers the power to servers on the well site for computing tasks at a small but mighty data processing center. Using satellite internet, the company digitally transfers the output product.

"Let's let our oil and gas industry have a piece of this computing economy," Cavness asserted.

Please see **POWER,** Page 10



Crusoe uses the excess natural gas, converts it to electricity and transfers the power to servers on the well site for computing tasks at a small but mighty data processing center. This deployment eliminates approximately 400,000 cubic feet of natural gas flaring per day.

PHOTOS COURTESY, CULLY CAVNESS

Power

From page 9

The problem

With the advent of fracking, operators have unlocked astronomical volumes of gas along with oil. But the sharp uptick in shale production has outstripped demand, causing gas prices to crater. Building a pipeline or transporting the gas to market by truck might cost a company. So, some turn to flaring.

But flaring also comes with its own set of shortcomings.

For one, many consider flaring to be a waste of a finite resource. Burning off natural gas also threatens surrounding air quality, given its release of contaminants like volatile organic compounds, methane, soot and others. The state also can't collect production taxes from flared gas, sending millions in potential revenue down the drain each year.

These consequences have led states such as Wyoming to impose limits on flaring. In the Equality State, companies cannot flare more than 60,000 cubic feet of natural gas per day from an oil well. Flaring that amount of gas per day at a well for one year burns enough gas to cover the heating and cooking needs of about 300 homes.

Crusoe's team has designed projects that can capture upward of 600 million cubic feet of flared gas a day.

If operators have an eye on an exploratory well and anticipate having extra gas on their hands, they must first go before the Wyoming Oil and Gas Conservation Commission and make a case for why flaring beyond the limit is absolutely necessary. In a far worse scenario, an operator must shut in, or stop activity, at a well altogether to avoid excessive flaring, a costly consequence.

Wyoming ranks fourth nationally in the amount of natural gas flared and vented. But the practice remains tightly regulated by the state, even as federal agencies relax emission requirements and open the gates to more oil and gas leasing. Wyoming's rates also pale in comparison to states like Texas and North Dakota.

"If the state is ever in a situation where this well just cannot be compliant from a gas standpoint and therefore the oil gets shut-in, that is a huge loss of royalties and revenue and taxes for that oil," Cavness said.

Cully Cavness, pictured right, and Chase Lochmiller co-founded Crusoe Energy Systems, a company determined to help oil and gas operators avoid flaring, or burning natural gas.

PHOTOS COURTESY, CULLY CAVNESS

A solution

As it turns out, computers consume an exorbitant amount of energy when they perform tasks such as bitcoin mining, artificial intelligence or other machine learning programs, Lochmiller explained.

"We're bringing some of that high-demand computing into the oil field," he said.

In doing so, Crusoe removes the need for companies to invest in costly and energy-intensive infrastructure to transfer the gas to market. Instead, the market comes to rural Wyoming oil sites.

At times, operators will look at the data processing center and think its equipment is straight out of the movie "The Matrix," Cavness said.

"The response initially (from companies) is: 'is this real? Can this really work?'" he explained.

But the company's ideas appear to be catching on.

At a Sept. 10 Wyoming Oil and Gas Conservation Commission hearing, oil company MCM petitioned to flare leftover gas at an exploratory well site in Goshen County.

The company agreed not to exceed 1,000 MCF per day (as a monthly average) and end flaring above the daily limit within six months.

But the company will also be siphoning some of that gas to Crusoe's data processing centers too.

"We left there feeling super validated that we were doing something that the commission liked to see," Cavness said.

The co-founders took that pivotal hike in June 2018. Fast forward a few dozen months, and the firm has over 15 digital flare mitigation systems planted on oil sites throughout the Rocky Mountain region — their home base. They hope to have 35 operations deployed as soon as June.

Crusoe's first project landed them in Wyoming, working with Thunder Basin Resources in the Powder River Basin.

"We've been really appreciative to the state for giving us that start," Cavness said.

Crusoe's two leaders haven't stopped climbing since launching their new company. The two enjoy endurance sports. The morning Cavness and Lochmiller spoke to the Star-Tribune, the pair had risen at 4:30 a.m. to run through the mountains for two hours.

"Running up and down these various mountains is what we refer to as our board meeting," Cavness quipped.

Follow the latest on Wyoming's energy industry at @camillereports

Flaring offers oil producers a way to rid the site of abundant gas. But flaring's effulgent flames obstruct horizons, contaminate the air and burn up state revenue. A new company called Crusoe Energy Systems came up with a solution.

FIVE FINALISTS COMPETE FOR
CARBON XPRIZE

The race is on. Scientists from around the world have been competing to successfully transform carbon dioxide emissions into an innovative product at Wyoming's Integrated Test Center. The winner receives $20 million from Carbon XPRIZE. Here are the five finalists coming to Wyoming.

C4X

C4X created an energy-efficient technology to transform carbon dioxide into various chemicals and plastics, including ethylene carbonate, an ingredient needed to build lithium-ion batteries. The process traps carbon dioxide with a 90 percent efficiency. Potential customers include textile, plastic and car manufacturers as well as lithium-ion battery suppliers for solar panels.

Location: Suzhou, China and Toronto, Canada

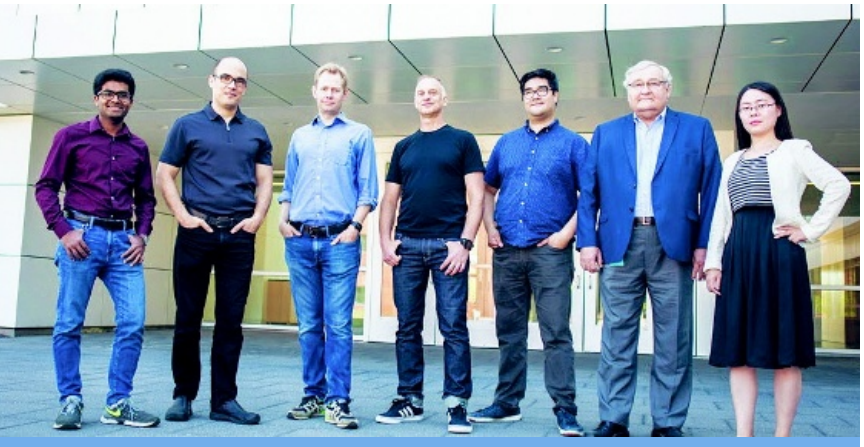
XPRIZE Test Site: Wyoming Integrated Test Center

BREATHE

Breathe uses waste carbon dioxide from power plants to create carbon monoxide and methanol, two chemicals used for a variety of industrial and manufacturing processes. For instance, methanol can be mixed with gasoline to lower emissions. The process lowers cost and emissions and would potentially enable India to source more methanol locally.

Location: Bangalore, India

XPRIZE Test Site: Wyoming Integrated Test Center



DIMENSIONAL ENERGY

Dimensional Energy invented a modular reactor technology, called a HI-Light reactor, that is powered by sunlight to make polymers and chemicals for a variety of industrial applications.

Potential customers include chemical pharmaceutical and fuel manufacturers.

Location: Ithaca, New York

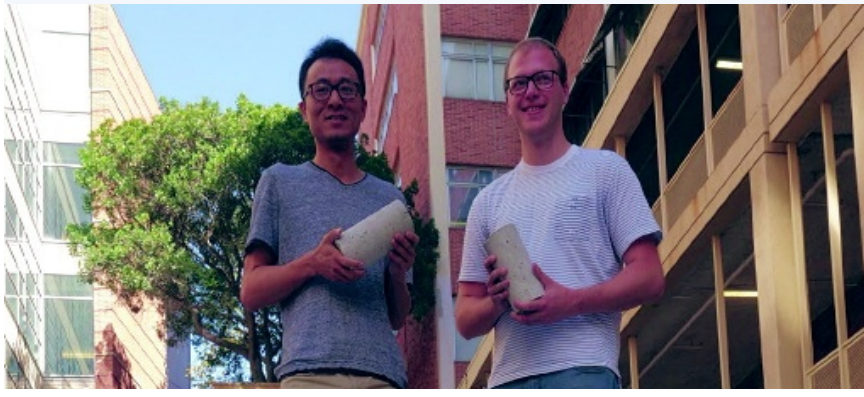
XPRIZE Test Site: Wyoming Integrated Test Center

CARBON UPCYCLING UCLA

Carbon Upcycling UCLA captures carbon dioxide to produce standard construction products, like concrete. When made under traditional manufacturing processes, concrete emits significant levels of carbon dioxide. Concrete contributes to 7 percent of the world's annual carbon dioxide emissions. This technology uses carbon dioxide from flue gas coming from a power plant and traps it in limestone to make concrete used in general construction.

Location: Los Angeles, California

XPRIZE Test Site: Wyoming Integrated Test Center



CARBON CAPTURE MACHINE

Carbon Capture Machine applies a mineralization process that mixes carbon dioxide with brine water to create valuable carbonate feedstocks used for plasterboard, paper coating, pharmaceuticals and adhesives.

Location: Aberdeen, Scotland

XPRIZE Test Site: Wyoming Integrated Test Center

PHOTOS COURTESY OF CARBON XPRIZE

A photographic look at

MESA NATURAL GAS

Company's technology makes use of excess natural gas

CAMILLE ERICKSON AND CAYLA NIMMO

Mesa Natural Gas Solutions LLC, a power solutions provider, is taking full advantage of the glut in natural gas. The Wyoming-based company helps oil and gas operators make use of the abundant, inexpensive resource.

Instead of using costly diesel to power remote oil and gas fields, Mesa Solutions engineered natural gas generators to fuel everything from pumping units to large micro-grids.

Funneling natural gas all the way to a customer often earns pennies on the dollar for an operator. So, many have to turn to flaring, a process of burning off excess natural gas. Though an oil and gas operator in Wyoming can flare up to 60,000 cubic feet of natural gas per day from an oil well, the practice is still discouraged by regulators. Flaring above the limit or shutting down production can be costly.

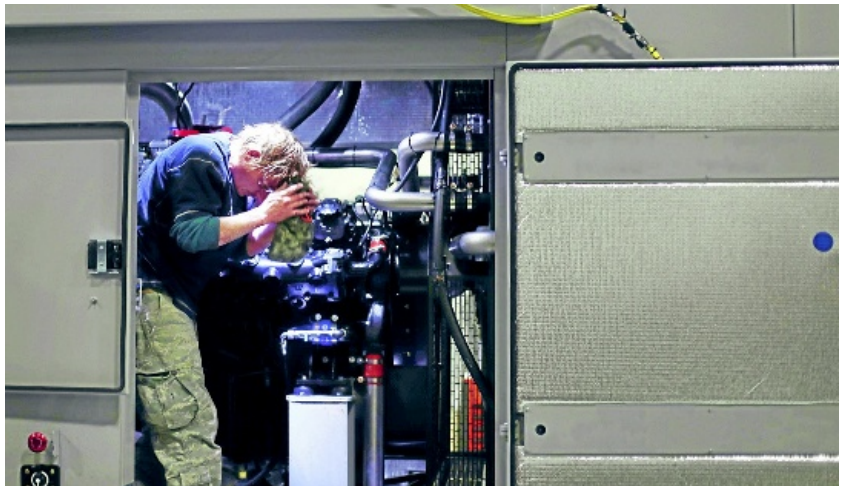
That's where Mesa Solutions leverages the wealth of natural gas Wyoming has on hand.

The company captures the stranded natural gas and converts it into electrical power for use on site.

Follow the latest on Wyoming's energy industry at @camillereports

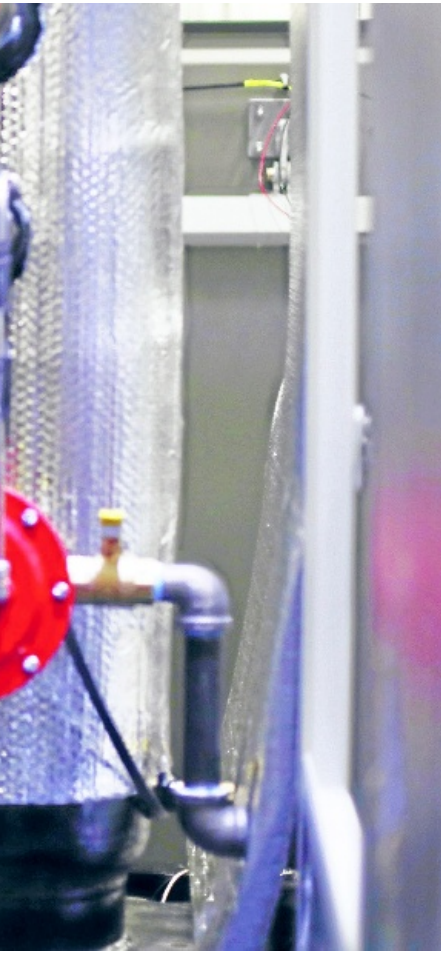
CAYLA NIMMO PHOTOS, STAR-TRIBUNE

Pat Humecky works on the external shell of a generator nearing completion at Mesa Solutions in Evansville. Mesa's generators are designed to power oil and gas wells with gas captured on site.

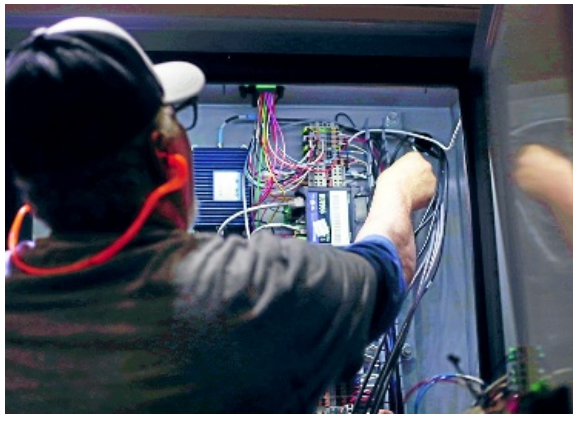


ABOVE: Roy Boatman works inside a Mesa Solutions generator nearing completion. Mesa's generators can run on natural gas or propane.

LEFT: Gary Bushnell, right, and Randi Clark, left, work on different stages of wiring while completing a panel that acts as the "brain" of a Mesa Solutions generator at the company's manufacturing facility in Evansville.



Cruz Cabral gives a tour of the Mesa Natural Gas Solutions warehouse in Evansville. Cabral stands between two generators in various stages of construction. The company has sent a number of generators to wine country in California in light of wildfires and blackouts there.



FAR LEFT: Completed generators produced by Mesa Solutions sit on a lot outside its shop in Evansville waiting to be shipped out. Each generator is tested on site before being sent to clients.

LEFT: Gilbert Vega secures wires in an external panel for a Mesa Solutions generator nearing completion on Nov. 21 in Evansville.

A question of utility

Can carbon capture be efficient, cost-effective and commercially viable all at once?

CAMILLE ERICKSON
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The University of Kentucky Center for Applied Energy Research (UK CAER) has a long record of researching carbon dioxide (CO_2) capture technology. The research team at UK CAER partnered with several utilities in their region over the past two decades and recently installed a small pilot-scale CO_2 capture facility at the Kentucky Utilities E.W. Brown Generating Station near Harrodsburg, Kentucky. It has been operational since 2015 and has over 4,800 hours of experimentation. The process circulates a liquid, called the solvent, to remove the CO_2 from the flue gas and produce a CO_2 product with an over 99.9 percent purity.

The Star-Tribune spoke with Kunlei Liu, principal investigator, and Heather Nikolic, co-investigator, about a carbon capture project that they plan to install at Wyoming's Integrated Test Center with financial support from their utility partners and the U.S. Department of Energy.

The conversation has been edited for clarity.

Casper Star-Tribune: You are planning to execute the third phase of your research into capturing carbon dioxide at Wyoming's Integrated Test Center. What benefits do you see the ITC providing for your research?

Kunlei Liu: Wyoming shares the same

FILE, STAR-TRIBUNE

The Dry Fork Station is home to the Integrated Test Center, which hosts researchers looking for ways to capture and monetize carbon emissions from the coal-burning process.

Water vapor rises out of a stack at Dry Fork Station in Gillette in 2019. Scientists from around the world are using flue gas from the power plant to test cutting edge carbon capture technology.

CAYLA NIMMO, STAR-TRIBUNE

goal as Kentucky in keeping coal a viable source for energy production in an environmentally responsible manner. The Integrated Test Center is one of the few places in the world built to host and facilitate the scale-up of technologies so that commercialization can happen. So, we're motivated to come to Wyoming because we want to advance our technology to deliver a more cost-effective carbon capture method and make it ready for commercialization. This scale-up step is critical to minimize commercialization problems and maximize the chances of success.

CAYLA NIMMO, STAR-TRIBUNE

Snow covers the ground at Dry Fork Station as production continues at the coal power plant in Gillette in 2019. Next to the plant sits the Wyoming Integrated Test Center, where engineers and scientists can use the testing facility to study carbon capture and sequestration technology.

Star-Tribune: What are you going to be doing at the ITC?

Liu: We are going to construct and operate our carbon capture process at the 10 MWe scale. All of our carbon capture technologies have been thoroughly tested at our small-pilot facility in Kentucky. At ITC we will be treating 15 times more flue gas with a process that is about one-half an acre in size.

We are always asking, "How do we reduce the cost of carbon capture?" We will test our modular configuration in Wyoming, continuing to reduce the capital, installation and operating costs with maximize electricity generation output.

Star-Tribune: Can you tell me a bit more about the technologies you plan to introduce and scale up?

Liu: To give you some technical details, we have developed a unique, solvent-independent carbon capture process with heat integration, compact columns, two-stage solvent regeneration, a split-rich primary stripper feed, advanced process controls and an energy loss minimization strategy. Our project is unique because these technologies work synergistically to strike a balance between the capital cost and the energy demand needed for CO2 capture. This may sound complicated, but it's analogous to replacing the steel used in cars with plastics. It makes the vehicle fuel efficiency better.

Star-Tribune: What makes what you're researching in the field of carbon capture unique?

Liu: At the beginning of carbon capture research, everyone was working on the solvent composition to reduce the energy demand needed to capture the CO2. They thought the solvent was the dominant factor to impact the carbon capture cost. So, they focused on this one element. Our philosophy is to reduce this energy demand close to what everyone else has done, but with a much lower capital investment. We consider all aspects: equipment sizing, process simplification and integration, heat recovery, the solvent composition and flexible operation. If you look at other technology developers, their process is designed specifically for their own solvent. Our process will work with most solvents. This is like having the freedom to buy a lower cost generic brand.

Heather Nikolic: Like Dr. Liu said, this is a robust process that we've developed here, with many focuses. It's solvent independent, meaning that it works well with most available advanced solvents. It's also a heat-integrated process, meaning we reuse waste heat that just typically is lost. We also apply several process intensification technologies to make the equipment smaller. Finally, I would just like to say that we're very excited for the opportunity to be working in Wyoming and we're looking forward to continuing our great relationship with the Integrated Test Center.

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THE RACE IS ON
at Wyoming's Integrated Test Center

The contest could have big implications for Wyoming's economy

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The race is on.

Five finalists are vying to successfully transform carbon dioxide emissions into an innovative product at Wyoming's Integrated Test Center.

Carbon XPRIZE, the competition's organizer, dangles the prospect of $20 million in prize money to motivate scientists, entrepreneurs and creative thinkers to come up with solutions to the world's most pressing problems. In this case, that problem is how to reduce the carbon dioxide emitted from power plants.

Finalists from around the world are now in the final stretch, feverishly working to transport their technologies to Wyoming's ITC this spring and test them out for a panel of judges.

The Star-Tribune interviewed Marcius Extavour, leader of the XPRIZE energy team, for the latest on the competition.

The interview has been edited for clarity.

GILLETTE NEWS RECORD, AUGUST FRANK

Dennis Thorfinnson points out different features of the Dry Fork Station to XPRIZE competitors Sebastian Peter, left, and David Erickson during a tour in 2019.

Casper Star-Tribune: Why did you chose to send your five Carbon XPRIZE finalists to Wyoming's Integrated Test Center to test their carbon technologies?

Marcius Extavour: Carbon XPRIZE has some deep Wyoming roots. Around 2010, XPRIZE first started sniffing around the idea of reducing emissions from power stations in places like Wyoming, where coal is pretty central.

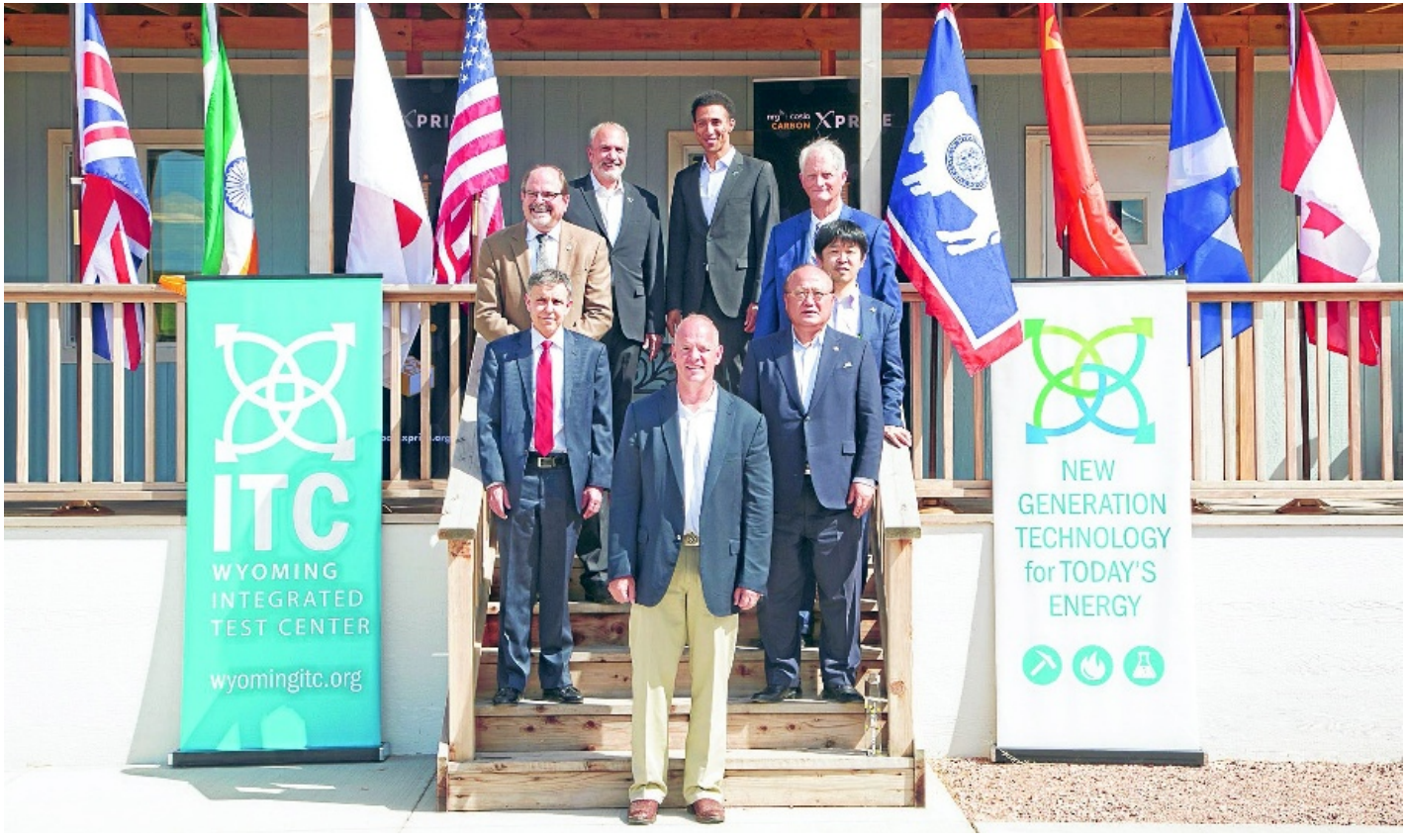
How can Wyoming move forward into a future where those sources are constrained? What if there is a carbon tax? What if there are new regulations? Already at that time, people were thinking ahead about how Wyoming could take a forward-looking view.

At the end of the day, I think Wyoming's interest in supporting and being a part of the Carbon XPRIZE story was based in this idea that Wyoming can help to shape the innovation of the future here. We can do that by using its resources, not just natural resources, but also its people and facilities. Specifically, can we can work with and develop an innovation center, a hub, where people can test these technologies?

That puts Wyoming in a good leadership position, and helps attract these ideas to the state. But it also helps Wyoming learn how to move forward in the years to come. It was a huge gift for XPRIZE companies to be able to use the site.

Star-Tribune: So what is Carbon XPRIZE?

Extavour: We're a nonprofit here in Los Angeles, but our competitions are global. That means we identify challenges, we design prizes, and we raise the money. We do open calls to innovators around the world to demonstrate solutions to a really pressing problem.



COURTESY, WYOMING INTEGRATED TEST CENTER

Supporters stand at the doors of the Wyoming Integrated Test Center during a dedication ceremony in May 2018. From left to right, starting front and center stands former-Gov. Matt Mead, Chief Executive Officer of Basin Electric Power Cooperative Paul Sukut, Senior Vice President of Business and Technology Strategies for the National Rural Electric Cooperative Association Jim Spiers, XPRIZE Board of Trustees Member Lee Stein, Senior Director of the Carbon XPRIZE Marcius Extavour, Chairman of the Board for Tri-State Generation & Transmission Association Rick Gordon, Director of the Ministry of The Environment Government of Japan Yoshihiro Mizutani and President of the Japan Coal Energy Center Osamu Tsukamoto.

Star-Tribune: Why focus on carbon?

Extavour: When we looked at carbon, we narrowed it down to the carbon utilization piece. We know we have to turn down our emissions. But one way to do that is to create a market incentive to show that the emissions are valuable. You can turn carbon emissions into useful materials. So, we want people to show real demonstrations of taking carbon emissions and turning them into something useful. And can you do that in a way that makes economic sense? Can you build a business around that?

Star-Tribune: What do you have to do to win the prize?

Extavour: Fundamentally, what the teams have to do to win is take a fraction of the emissions coming out of the Dry Fork Station power plant in Gillette and turn the carbon dioxide into a useful material, any material that they want. They can use any technology they want. They are going to be judged by how valuable it is, how energy efficient it was, how much carbon they can actually use up. That's basically what the teams are racing to get done.

Star-Tribune: What's the status of the teams?

Extavour: None of them are installed there (in Wyoming) yet. So if you go to the ITC today, you won't see them there. But they are all racing to get there in the next few months by the deadline of the competition. They have all chosen to more or less build up their technology structures where they are based now and then ship them in. Whoever is going to come through and really go for it and try to win this prize, they've got to do it in the next few months. The race is on.

Star-Tribune: Tell me more about the five finalists.

Extavour: There are five competitors in Scotland, India, California, New York and China. Each of those teams has a dedicated spot at the ITC for testing a different technology to make that material with the captured carbon dioxide.

They are literally racing now to get to the site so they can get there in time to set up their project, and try to win this prize. All these teams had to overcome a lot of hurdles. They had to figure how to operate at a site that is away from home. They have to figure out how to ship their technology. They had to raise a lot of money to do this on their own. That's all part of the prize.

We don't know if all of the five teams are going to be able to make it to the site. We don't know yet which one is going to be successful. All these teams think that they can do it. They all want to win. They all have amazing technology to showcase. The question is if they can execute it in the next six months and who will take home the prize.

The winner will be announced in the fall.

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Tools and fittings used in testing rocks and fluids seen in oil reservoirs are seen in November 2013 at the University of Wyoming's Enhanced Oil Recovery Institute laboratory, then located in Laramie.

FILE, STAR-TRIBUNE

WELL EQUIPPED

Now in Casper, Enhanced Oil Recovery Institute continues to hone new technologies

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The Enhanced Oil Recovery Institute, or EORI, aims to propel energy technology and innovation forward for the benefit of oil producers and the state of Wyoming.

Though it's considered one of UW's Research Centers for Excellence, you'll find the research hub in Casper, not Laramie. That's a relatively recent development, spearheaded by Director Steven Carpenter.

The institute now occupies a wing of the Wyoming Technology Business Center on King Boulevard and sits adjacent to the Wyoming Oil and Gas Conservation Commission and near the Wyoming Pipeline Authority. The relocation has strengthened the agency's connection to energy entrepreneurs and technology developers, according to Carpenter.

EORI provides independent operators throughout the state with access to relevant research conducted by the institute's robust staff of geologists, engineers and economists.

Carpenter said they work to pinpoint "broader problems" afflicting a significant portion of the industry. They then independently vet new technologies to boost the state's oil production and maximize efficiency for secondary recovery. In other words, the institute tests technology to de-risk it for companies operating here.

"Our mission is to advance technology and get it into the hands of the operators," Carpenter said. "What we do gets published in the public domain and gets shared for the benefit of all of Wyoming and our stakeholders."

The latest

At the tail end of 2018, the EORI partnered with Merit Energy Company to test out methods for identifying stranded oil resources. The EORI and Merit Energy teamed up to piloted the study at two mature fields in the Bighorn Basin.

Even fields that have already produced several wells often hold residual oil. But over time, pressure lowers and production isn't as robust. That leaves operators

little choice but to plug and abandon or "shut in" a well due its lack of economic return.

Operators can potentially reach the remaining oil by injecting water into wells to increase pressure underground and push out more oil from proximate wells. But it's often difficult to identify which injection wells are the most effective to use.

In a tracer study, Merit Energy injected chemically different, traceable substances into various injection wells. That way, when water came up from a producing well, they knew exactly where the water originated.

Merit Energy chipped in $43,000 to go toward project costs. EORI provided a $20,000 grant. The study yielded an additional 80 barrels and 150 MBO reserves for Merit Energy, with associated taxes flowing back to the state.

What to look for

The institute is now looking for Wyoming oil and gas operators willing to participate in a new study on paraffin problems. Paraffin is a waxy substance that can accumulate on equipment and slow down production.

EORI is searching for 15 wells to test out its Microbial Treatment Field Test Study.

The qualifying wells will be selected by May 1.

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FILE PHOTOS, STAR-TRIBUNE

Haifeng Jiang, a research scientist at the University of Wyoming's Enhanced Oil Recovery Institute laboratory, works with a vessel used for liquid transfers in November 2013.

Rock samples are set out for testing in November 2013, at the University of Wyoming's Enhanced Oil Recovery Institute, then in Laramie.

Monitoring reclaimed sites can be tedious, but new digital technology can lend a hand

FILE, STAR-TRIBUNE

A well site is pictured in 2019 near the Lincoln-Sweetwater county line. When oil and gas operators finish drilling, they must reclaim, or restore, the land. Federal regulators require annual monitoring reports to ensure biodiversity of the site is maintained for years to come.

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When oil and gas companies plug and abandon a well pad and end production on public land, the work isn't over. The Bureau of Land Management requires that operators clean up, or reclaim, any disturbed acreage.

That means reviving soil and vegetation to its previous state, or one that can support wildlife and livestock. For years afterward, operators then must monitor the federal land to sustain restoration efforts and promote biodiversity. Companies then submit these annual monitoring reports to federal regulators.

But keeping up these monitoring efforts can prove tedious and labor intensive.

Pete Stahl is a University of Wyoming professor and director at the Wyoming Reclamation and Restoration Center. He's led the charge to research new methods for monitoring reclaimed land. One involving image-based sampling has proved significantly less labor intensive and can provide more accurate data than current practices.

Recently, some of the Bureau of Land Management field offices in Wyoming approved the new digital technology for use. The technology is still in its test phase, though, and not widespread.

In more traditional methods of reclamation monitoring, scientists would take several hours to evaluate a single, 50 meter-long transect, or designated portion of a field.

According to Stahl, this task would typically take two people and half a day. Statisticians analyzing the data need data from several transects to ensure the results are accurate.

"We are promoting these new photographic techniques, where you go out and walk around the site and take pictures at predetermined intervals," Stahl explained. "We take a photograph of each one of these sites, stored in the camera, so now we have a permanent record of what we've seen."

Instead of being limited to one to two sites per day under the old methods of monitoring, the digital method allows for more efficient and accurate data collection. Just a portion of the process requires monitoring companies to be out in the field. And the analysis can be conducted from a computer in comfortable conditions, he said.

The Bureau of Land Management looks to maintain diverse plant species and root out weeds like cheat grass. Proper reclamation of land also prevents erosion.

Stahl is also studying possible applications of drone technology in reclamation monitoring. These "unmanned aerial systems" can accomplish the job of capturing digital images of reclaimed well pads even faster than on-the-ground photography. What's more, one free software program called SamplePoint can help companies quickly identify the species of various plants the images capture or determine the level of ground cover on former oil and gas fields.

But as is usually the case, there's still more work ahead.

"There continues to always be a need for developing better methods," Stahl pressed.

Wyoming has harsh environments to work in with short growing seasons and low precipitation rates.

"We do have a relatively high failure rate," Stahl said. "We need to come up with better methods to avoid that and we're always trying to improve what we do."

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Black Jones, a manager for Cloud Peak Energy, shows reclamation work underway in 2016 at Antelope Mine in the Powder River Basin. The grass was planted after the dirt was replaced in layers.

FILE, STAR-TRIBUNE

The hottest thing in solar energy? PEROVSKITE CELLS.

Sweetwater Solar is the first utility-scale solar energy farm in Wyoming. Solar panels made with a material called perovskite could enter the commercial market in the near future, some scientists predict.

Material is abundant, efficient and relatively easy to manufacture

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Solar energy scientists have been on the hunt for the most effective solar cell — one built from materials that can convert sunlight into electricity as efficiently and economically as possible. But finding those ideal materials can be tough. When it comes to utility-scale solar, companies overwhelmingly install solar cells made from silicon. Yet silicon's dominance in the commercial market of solar doesn't mean other options don't exist.

A new material called perovskite has taken the field of solar energy by storm in recent years and holds commercial promise. University of Wyoming chemistry professor Bruce Parkinson called research into perovskite solar cells "the hottest thing in photovoltaics."

Solar cell materials need to be abundant, relatively easy to manufacture and effective at absorbing sunlight efficiently at an ideal wavelength for producing electricity.

"The really great thing about perovskite cells is that they tick all those boxes," said David Ginger, chief scientist at University of Washington's Clean Energy Institute.

FILE PHOTOS, STAR-TRIBUNE

The Sweetwater Solar energy project, which covers about 700 acres northwest of Green River, is pictured in 2019. Recent innovations have increased the efficiency of solar cells.

Scientists have been able to build perovskite solar cells with record efficiencies of roughly 25.2 percent in recent years. In other words, about a quarter of all the energy packed into the sunlight that hits the solar cell is converted into electricity.

To Ginger, these recent leaps in perovskite development are a big deal.

"In just a few years, the material's efficiency is now close to — though not quite as good — but close to, where silicon solar cells are," Ginger said.

Scientists, armed with lessons learned from experimenting with silicon, were able to advance the efficiency of perovskite cells in record time.

But problems still persist. Perovskite contains lead, which is toxic to humans.

Ginger remains confident researchers will overcome these hurdles and likely make perovskite feasible for utility-scale solar in the somewhat imminent future.

For one, the level of lead is relatively low, not any more than what's found in car batteries, Ginger said. When applied to a solar cell, the active layer of perovskite is extremely thin, significantly thinner than the diameter of a single human hair. That means its environmental impact is likely less than the heavy metals emitted from the combustion of coal.

Still, researchers have been on the hunt for safer, lead-free formulations of perovskite, and new ways to seal the perovskites from the environment.

"I'm optimistic that in the next few years that we can get there," Ginger said.

To reach higher efficiencies, researchers have been experimenting with tandem solar cells to make perovskites more efficient and capable of generating more power from the sunlight it absorbs.

Ginger compared a tandem solar cell to a tandem bicycle, or a bicycle built for two people. A tandem solar cell is composed of a pair solar cells stacked one on top — like perovskite and traditional silicon. Combining the forces of these two components can lead to a more efficient solar panel with fewer defects.

Though perovskites haven't been applied yet on a large-utility scale, several companies around the world are racing to commercialize the new technology.

But perovskites are more resilient to defects than other photovoltaic technologies, potentially making them cheaper to manufacture.

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‘A new focus and path’

Different approaches in problem-solving will be needed for wind energy to fully catch on

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When it comes to the mammoth machines transforming wind into electricity, technological advancements have exploded in the past half-century, arguably revolutionizing the electricity grid.

But wind power still produced just 6.5 percent of the nation’s electricity in 2018. That’s not to say wind energy is dead. In fact, likely the opposite. Innovations in the field of wind energy science could catapult the renewable resource into the top ranks of energy markets.

Wind and solar energy could provide one-third to half of the country’s electricity demand by 2050, several scientists predict. Low-carbon fuel sources will also be a critical part of the country’s energy portfolio as public concerns about human-driven climate change mount. What’s more, costs for wind energy have achieved parity with other, prolific energy sources, with costs for wind hovering around $0.04 per kilowatt-hour.

The hurdles faced by the industry writ large will require the expertise from a whole suite of disciplines. That’s according to a paper published recently by a couple dozen scientists, including University of Wyoming’s own wind expert Jonathan Naughton.

“The argument in the article is that we need a new focus and path, which is called wind energy science,” Naughton said. “Wind moving forward is not a single discipline.”

Naughton and his fellow authors outline a set of challenges facing the increasingly cross-disciplinary terrain that is wind energy science — from global weather effects and electric system functionality to turbine dynamics. To improve the performance of wind turbines, several puzzles need to be researched, but it’s doable, Naughton said.

“It’s not like this is an insurmountable obstacle,” he noted.

Naughton provided the example of aerospace science, a field of study that fuses the knowledge of electrical, civil and mechanical engineers.

Wind energy science will require a similar open-minded approach and what the authors of the report called a “physics across an increasingly large range of spatial and temporal scales in the atmosphere.”

Here are the three challenges Naughton and his colleagues say the field of wind energy science still needs to wrestle with:

Challenge No. 1: How does the wind blow?

Americans wake up in the morning and have several options at their fingertips to check the weather. But scientists still have yet to fully grasp the

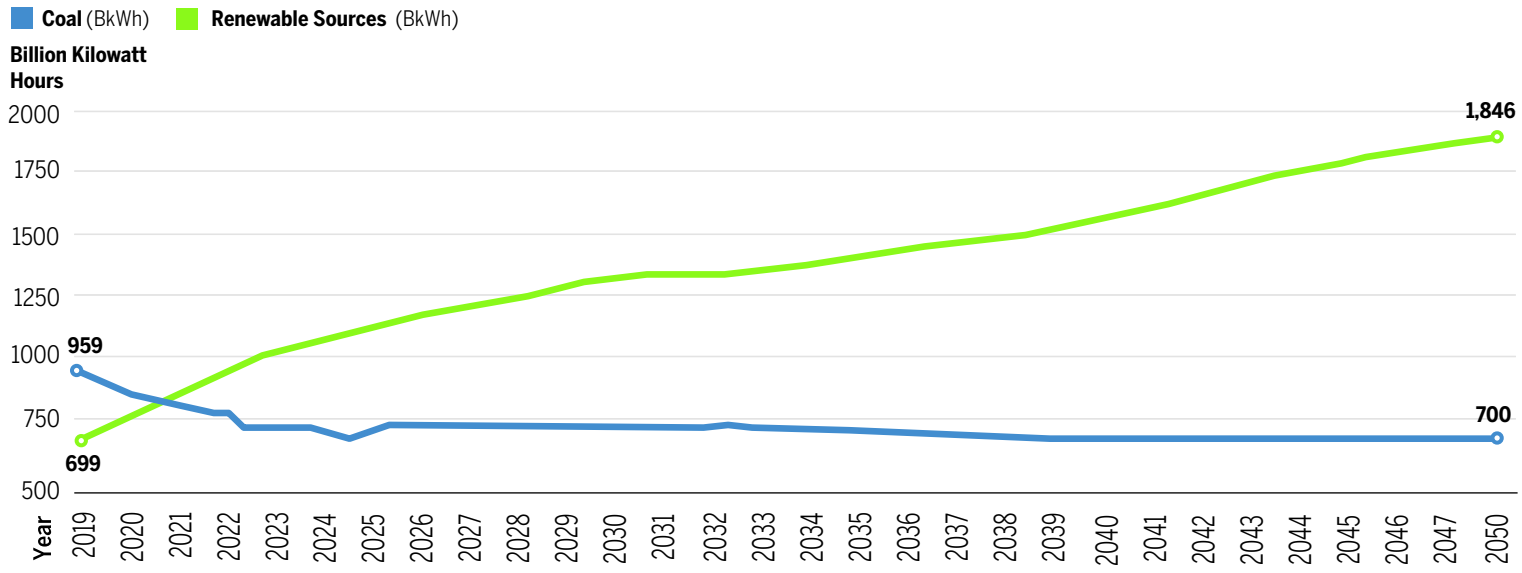
Please see WIND, Page 27

Wind turbines spin along the Shirley Basin north of Medicine Bow last year. University of Wyoming professor Jonathan Naughton and his fellow authors outline a set of challenges facing the increasingly cross-disciplinary terrain that is wind energy science — from global weather effects and electric system functionality to turbine dynamics.

CAYLA NIMMO, STAR-TRIBUNE

Renewables forecast to supply more electricity than coal soon

Wind and solar energy could provide one-third to one-half of the country's electricity demand by 2050, several scientists predict.



Source: U.S. Energy Information Administration

Lee Enterprises graphic

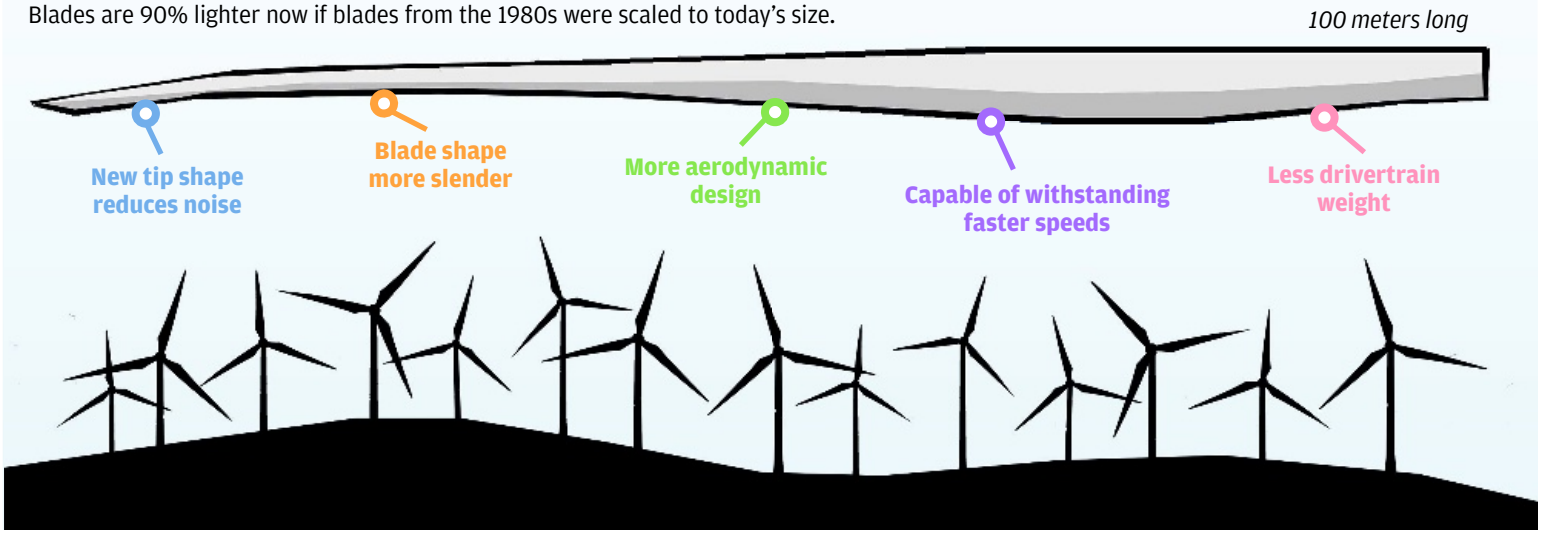
Transformations in turbines

Engineers continue to look for ways to update and improve wind turbines blades to perfect the physics of turning the machines in near constant rotation or movement into consumable energy.

1980s blade

Current generation blade

Blades are 90% lighter now if blades from the 1980s were scaled to today's size.



Source: AAAS Science Mag

Lee Enterprises graphic

Wind

From page 25

fickle behavior of the wind. That's especially the case with low-level winds, or the winds closest to the earth's surface.

Low-level wind doesn't have much of a role in influencing the weather. Yet what wind is doing in the first 2,000 feet from the ground, also called the boundary layer, is critical to wind energy scientists. This zone near the surface happens to be right where wind turbines operate.

"These low-level winds — where turbines operate — is still an area that we really don't understand very well," Naughton said. "As you can imagine, it has a huge impact on wind plant development."

Take blustery Wyoming as an example: the landscape — often considered one of the best resources for wind energy — has a plethora of valleys, ridges, mountains and other landforms that make the way wind blows incredibly variable.

"How winds behave around those (landforms) is really tough to understand," Naughton said. "What we want to do is expand our knowledge of how winds behave at these lower levels. If we understand that better, we can develop wind farms and wind turbines better."

Scientists can measure wind speeds using meteorological towers or radar technology. A recent technology known as Lidar System has enabled scientists to measure wind remotely. But more research is needed.

Challenge No. 2: A complete makeover in design

Wyoming's first wind farm, installed in 1999, flaunted around 68 wind turbines spinning in Carbon County. The owner of the fleet, Rocky Mountain Power, announced last year it would upgrade the wind farm by replacing the turbines. Thanks to technological advancements, the company installed just about a dozen turbines, albeit much more powerful and taller. That's because wind blades, generators and the towers have only grown in scale and efficiency.

"These are enormous, enormous machines," Naughton said.

Power Company of Wyoming is planning to open the largest wind farm in the world on Wyoming soil. The company plans to install 396 turbines in the second phase of wind development for the Chokecherry and Sierra Madre Wind Project. The fleet will produce 1,500 megawatts of capacity. In comparison, for phase one of the project, the company has plans to install 500 turbines for that same amount of capacity (1,500 megawatts), according to Kara Choquette, Power Company of Wyoming's communication director.

"Power Company of Wyoming has not yet identified the turbine models or vendors that would be used, and we won't until closer to the time when the turbines themselves would be installed a few years from now," she said in an email.

Blades are about 90 percent lighter than their predecessors from the 1980s, if scaled to today's length. These design elements are constantly being improved and updated as wind turbines increase in size to perfect the physics of turning the machines in near constant rotation or movement into consumable energy.

The catch for scientists is to continue innovating these wind turbines to be as efficient as possible, without hiking up the price to keep parity with other fuel sources, Naughton said.

CAYLA NIMMO, STAR-TRIBUNE

Wyoming Highway 487 leads to a line of wind turbines in 2020 in the Shirley Basin north of Medicine Bow. Innovations in the field of wind energy science could catapult the renewable resource into the top ranks of energy markets.

Challenge No. 3: Looking toward a modern grid

Wind energy has to be fully reliable and meet the intensive demand of the electric grid too, the report concluded.

When people reach for a light switch, they expect a light to come on in turn. But wind can be somewhat unpredictable. Integrating wind energy into existing electric grids also poses a challenge for wind energy scientists. In other words, the way we think about the grid will also need to change, according to Naughton.

"Wind must provide more predictable and controllable power as well as services that support grid reliability stability and formation," the report states. "Wind power plants today can support many of the needs of the current grid, but additional research is needed to address how wind plants of the future and the their special attributes can be used to service the demands of a converter-based grid."

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