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ALERT TOP STORY

FUELING CHANGE IN WYOMING

Carbon capture may not be coal's savior. But it could spawn an industry all its own.

Nicole Pollack
Nov 21, 2021

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 flue gas to study carbon capture and sequestration technology.
Cayla Nimmo, Star-Tribune

Nicole Pollack

Eleven years ago, Wyoming was worried about its coal plants. Not because of waning demand — coal production **had just peaked** — but because the Obama administration wanted to see carbon capture commercialized by 2020.

The former president's contentious Clean Power Plan wouldn't be unveiled for another five years. Already, though, his administration was contemplating requiring that new coal-fired power plants capture and store their carbon emissions. State leaders feared such an order might also be extended to existing coal plants. And they weren't sure the industry could survive.

In 2010, just **one-third** of Americans saw climate change as a very serious problem — a number that has since **doubled**. The economy-wide shift away from carbon was still in its infancy. Politically, and technologically, the administration's carbon capture strategy was ahead of its time.

That's no longer the case.

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"Wyoming is in the thick of the energy transition," said Charles Nye, a research scientist in the Center for Economic Geology Research at the University of Wyoming.

"This is an energy transition that's an economic and political reality, whether we

like it or not. And so the best thing we can do is to surf the wave, rather than get pulled under."

When the Clean Power Plan arrived in 2015, it brought the nation's first carbon dioxide limits for coal- and gas-fired electricity generation. Carbon capture still wasn't market-ready; retrofitting wasn't on the table. Instead, states could decide how to meet the individual emissions goals set for them by the Environmental Protection Agency.

But in Wyoming, where coal mining alone **then contributed** more than one-tenth of all government revenues, and **90% of electricity** came from coal, the relative flexibility of the Clean Power Plan didn't alleviate the state's worries. A fringe idea was gaining traction: that the life of the coal industry could hinge on its ability to cut emissions. For the biggest U.S. coal producer, it was a frightening prospect.

"If all of that entire industry goes away for the state of Wyoming, not only is it the billion-plus worth of tax revenue coming into the state, it's also all of those jobs," said Jason Begger, then-director of the Wyoming Infrastructure Authority. "Wyoming was looking at, well, how do we get out in front of it? What can the state do?"

The Clean Power Plan didn't last. Decarbonization did. And carbon capture is nearing market readiness at last.

"We've been working on the technical research for a long time," said Holly Krutka, director of the School of Energy Resources at the University of Wyoming. "We now also have a strong research program on the policy side, to understand what it will take to actually get this technology off and running, driven towards commercialization."

These days, not everyone is convinced that carbon capture can — or should — save coal. But it's largely because of coal that Wyoming now houses some of the most

advanced carbon capture, utilization and storage (CCUS) projects in the world.

As carbon capture technology advances, that infrastructure represents a head start for a state looking to boost its economic prospects.

Surfing the wave

As coal plants go, Dry Fork Station is one of the cleanest. Situated at the mouth of the Dry Fork Mine, just north of Gillette, the 422-megawatt plant came online in 2011, equipped with state-of-the-art emissions controls designed to capture just about everything. Except carbon.

Then former Gov. Matt Mead announced in October 2015, two months after the Clean Power Plan was finalized, that a $15 million carbon capture test facility would be built at Dry Fork Station, funded jointly by the state and private companies.

Lab-based carbon capture research was already proliferating by then, including at the University of Wyoming; small-scale testing on real flue gas could be conducted at the National Carbon Capture Center. But at the time, only one sizable testing facility existed — in Norway.

"Ultimately, (the state) decided that there really was this gap in testing capabilities within the U.S.," Begger said. "In order for a utility to feel very comfortable that yes, this will scale up, this will work, all the systems will integrate together, they needed to see something at a 10- to 20-megawatt scale."

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Wyoming's carbon capture research hub, the Integrated Test Center, doesn't house any permanent research efforts. It functions more like an incubator for new technologies.

The Integrated Test Center can divert about 5% of the power plant's emissions, up to 20 megawatts of real flue gas, to its research bays. Begger, now the facility's managing director, said that while coal plant emissions can be approximated for lab research, "at some point, they have to test it on the real thing."

By the time the facility opened in 2018, another major CCUS initiative had followed it to Dry Fork Station: the Wyoming CarbonSAFE project, a federally sponsored carbon storage feasibility study led by the University of Wyoming. The current phase alone — stage three of five — is a $19.5 million project.

"The whole goal, at the end of this next phase of CarbonSAFE, is to have a fully characterized, permitted site that can be used for large-scale CO2 injection," said Scott Quillinan, senior director of research in geology at the University of Wyoming School of Energy Resources.

Wyoming and North Dakota are the **only two states** authorized by the Environmental Protection Agency to permit their own carbon injection wells, simplifying the still-rigorous process. Quillinan expects permitting to be finalized within the next few years.

Meanwhile, a new company is getting ready to set up shop at the Integrated Test Center. California-based Membrane Technology and Research won a $51.7 million grant to continue testing its novel carbon capture technology, which was already vetted successfully at the National Carbon Capture Center, at Dry Fork Station.

If this scaled-up version shows similar promise, it could yield the first captured CO2 injected into the neighboring CarbonSAFE well. Ultimately, researchers aim to store at least 2 million tons of CO2 at CarbonSAFE per year. The site is required to have a minimum of 50 million tons of total storage capacity.

"The idea is, in 2024, we would have our storage site all ready to go," Quillinan said. "Membrane Technology (and) Research would have their capture technology all ready to go. We would marry them up and then begin the project."

From lab to market

Carbon dioxide makes up about 12.5% of coal flue gas. The companies taking up shop at the Integrated Test Center want to separate and trap as much of that CO_2 as possible.

The most established methods of capturing carbon rely on liquid amines — nitrogen-containing organic compounds derived from ammonia — to pull the CO_2 out of flue gas.

"That exhaust gas stream is bubbled up through a liquid, which captures the CO_2," Begger said. "Everything that's not CO_2, most of the gas, is released and vented as normal. That CO_2-rich liquid is then heated up, which releases the CO_2. And then that liquid is then cooled back down, which makes it able to capture CO_2 again, and then just cycled through the system over and over again."

It's effective. Carbon capture technology from one leading developer, Tokyo-based Mitsubishi Heavy Industries, now comes with a performance guarantee for at least 90% capture. Mitsubishi's commercially established system was installed at scale at Texas' Petra Nova coal plant in 2017.

But liquid amines have a considerable weakness: cost. All that heating and cooling requires a huge amount of energy. Economic troubles during the COVID-19 pandemic caused Petra Nova to shut down the carbon capture project last year.

Moreover, if fossil fuels are used to power those energy-intensive liquid amine processes, a system's net carbon reduction can quickly dwindle.

That's where newer, more energy-efficient technologies come in. Some approaches build on older concepts: Kawasaki Heavy Industries, another Tokyo-based carbon capture developer, is scheduled to begin testing a dry version of the amine method at the Integrated Test Center in 2023.

"The idea is, if you're using a powder, it could reduce those costs even further,

because you wouldn't need as much heat and energy to do that heat exchange cycle," Begger said.

Other methods, like membrane technology, look very different. The advanced carbon filtration systems force flue gas across a selectively permeable membrane, separating CO2 from the rest of the exhaust.

Multiple companies have arranged to study membranes at the Integrated Test Center over the next several years. If the technology works, they're confident it will have an economic edge over liquid amines.

"You don't have that heat cycle," Begger said. "That's completely removed. So your operational energy costs should be reduced."

Membranes have yet to be demonstrated at a commercial scale. For Membrane Technology and Research, that crucial stage of the development process will begin at the Integrated Test Center next year.

Wyoming's head start

Once carbon is captured, no matter the mechanism, it has to go somewhere. Researchers are making headway on a range of utilization technologies, from using it to grow algae to converting it into fuels, chemicals, plastics and cement.

Wyoming is one of a handful of states that already has an established industrial use for CO2. The gas has been injected into certain oil wells to boost output, a technique known as enhanced oil recovery, since the 1980s.

When wells are drilled, the difference in pressure brings some oil to the surface. When production drops off and other methods, like flooding the site with water, have been exhausted, operators may inject CO2 to keep the well producing.

Deep underground, under immense pressure, CO2 attaches to oil molecules, causing more oil to rise to the surface. When the pressure falls, the CO2 detaches

from the oil. Operators then recapture the CO_2 and inject it back into the well.

Once all the oil has been extracted, the well is sealed off, trapping the CO_2 in the underground reservoir — and making enhanced oil recovery the only commercial sequestration industry.

It's a controversial practice. Academia is divided on whether, and how significantly, the carbon pumped into the ground offsets the carbon being extracted; all of the other environmental concerns about drilling still apply.

For years, the biggest climate draw of enhanced oil recovery has been the built-in profit: the prospect of using it to pay for the infrastructure needed to capture, transport and store CO_2.

"People need financial support through tax credits or federal dollars for storing to make these projects economic," said Lon Whitman, acting director of the Enhanced Oil Recovery Institute, a state agency that also operates through the University of Wyoming. "You would have no revenue for storage. So how would you possibly get your money back?"

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Existing incentives through 45Q, the federal tax credit for carbon sequestration, haven't done much for storage projects. Capture-to-storage facilities are currently eligible for a **$50-per-ton credit**, compared with $35 per ton for enhanced oil recovery. But the nearly $2 trillion budget reconciliation bill, which passed in the House of Representatives on Friday, would raise the storage credit to $85 per ton.

According to industry, the boost could **transform the economics** of carbon storage in the coming years. If the new tax credit becomes law, "the incentive potentially could be much higher for permanent storage versus enhanced oil

recovery," Whitman said.

But, he cautioned, "everyone really needs to wait and see what happens."

CO_2 currently used for enhanced oil recovery in Wyoming is extracted alongside natural gas, not captured from combustion. It's distributed from a single facility, ExxonMobil's Shute Creek gas plant, and transported to enhanced oil recovery projects through one of the country's only CO_2 pipeline systems.

The CO_2 pipeline travels diagonally across the state, from Kemmerer in the southwest through Gillette in the northeast — where Dry Fork Station is located — and extends into Colorado and Montana.

Growth of enhanced oil recovery has been suppressed by volatile oil prices, the limited CO_2 supply and the high costs of linking the existing pipeline to new parts of the state, including attractive but hard-to-reach oil reserves in the Bighorn Basin, Whitman said.

But if carbon capture can be installed at some of the state's power plants, he said, extending the pipeline to those facilities would solve the supply issue. More enhanced oil recovery projects might be incentivized to take advantage of the added supply, leading to expansion of the pipeline. Or, depending on the economics, the pipeline could be connected directly to storage sites.

Putting it back

Wyoming was exploring dedicated storage before CarbonSAFE came along. A year before Obama called for the commercialization of carbon capture, the University of Wyoming began studying geologic storage potential at the Rock Springs Uplift in southwestern Wyoming.

"We were some of the first in the country looking at this," Quillinan, the UW geologist, said. The researchers later wrote a textbook on best practices for geologic characterization, which informed the permitting process adopted by the

Department of Energy.

A decade later, "because all the geologic work has been done at the Rock Springs Uplift, it's now being targeted for commercial development," he said.

And when the university's focus shifted from the Rock Springs Uplift to CarbonSAFE in 2017, all that work on methodology paid off. Researchers completed their site characterization study in about half the time, he said, with about half the budget.

Carbon storage projects tend to focus on geologic layers that are deeper underground than the formations typically targeted for oil and gas drilling, Quillinan said. "That way, we know that in the future, if somebody is exploring for oil and gas, they're not going to drill through these formations."

They also look for formations that have suitable porosity and permeability for carbon storage.

"The porosity tells you how much void space you have inside the rock, so the space between the minerals, and the permeability means how well those void spaces are connected together," Quillinan said.

Sandstone and carbonate reservoirs are particularly likely to meet that criteria. Wyoming has a lot of them.

For CarbonSAFE, researchers are targeting the Minnelusa formation. A key source of oil in other parts of the state, it's full of saltwater at the project site, meaning storage wouldn't conflict with other uses. And it and the Hulett formation, another storage candidate, are both covered by a thick layer of shale that would hold the CO_2 in place for geologic timescales.

That far underground, CO_2 behaves more like a fluid than a gas, Quillinan said. Modeling indicates that once a well is sealed, the CO_2 will stabilize and stop moving, further reducing the already low risk of leakage. Monitoring systems,

which track CO_2 levels and other environmental factors that would change if the CO_2 started to escape, are installed in the target formation and on the surface above it, just in case.

Those technologies are advancing, too: A team of University of Wyoming students won $100,000 in XPRIZE funding this month to improve the design of a carbon soil gas sensor already collecting baseline data at the CarbonSAFE site.

Carbon capture after coal

Point-source carbon capture, the type being studied at Dry Fork Station, is different from atmospheric carbon removal, which still faces prohibitively high costs and has yet to be demonstrated at a commercial scale in the U.S. Both are still too costly for widespread adoption.

"When you launch new energy technologies, they are more expensive at first, and then the costs come down over time," Krutka, from the UW School of Energy Resources, said. "We've seen that again and again. And it's not just energy — that happens in all industries. So our goal is to try to get some of these early-mover projects up and running, and try to help bring the cost down for the overall technology."

The federal infrastructure bill that passed on Monday allocated more than $12 billion toward carbon capture, removal, utilization, transport and storage. Wyoming expects to see a substantial share of that funding support its CCUS work.

"It's really the government's role to help move a lot of these technologies, across the spectrum, especially in the demonstration space, to get it to where deployment is commercially viable, and where the private sector can really pick it up," said Shuchi Talati, chief of staff for the Office of Fossil Energy and Carbon Management at the Department of Energy.

Despite Wyoming's efforts to keep its coal plants open, the growing number of early coal plant retirements, coupled with the absence of new construction, mean

that even with those billions of dollars in federal support, commercial carbon capture will likely arrive too late for most of the U.S. coal fleet. The state's biggest utility plans to shutter its last coal plant in the state **by 2039**. Today, most experts expect retrofitting to make economic sense only at very young plants like Dry Fork Station.

But Wyoming CCUS infrastructure has a future outside coal. The federal government is eyeing adaptation of carbon capture technologies for use at natural gas processing facilities and gas-fired power plants, along with hard-to-decarbonize industrial sectors like cement.

Meanwhile, Wyoming's existing CO2 infrastructure, capture and storage research and natural gas reserves have all made the state particularly attractive to the **nascent clean hydrogen industry**.

"If we look at what our climate goals are, and where fossil fuel infrastructure is, there's no getting around that we need carbon capture and storage," Talati said. "Net-zero by 2050 isn't the end-all deal. We need to continue to pursue carbon removal, as we strive to limit harm to climate-vulnerable communities and nations."

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By Nicole Pollack

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