Western Confluence

Winter 2017 Issue 7

NATURAL RESOURCE SCIENCE AND MANAGEMENT IN THE WEST

OUR ENERGY FUTURE

Carbon Capture

Modernizing the Grid

Wyoming Wind Development

Net-Zero Energy Homes

A publication of the William D. Ruckelshaus Institute at the University of Wyoming's Haub School of Environment and Natural Resources

Western Confluence

Emilene Ostlind, Editor
Nicole Korfanta, Associate Editor
Tana Stith, Graphic Designer
Jessica Perry, Web Designer

Advisory Board

Anne MacKinnon
Chris Madson
Gregory Nickerson
Randy Teeuwen

Haub School and Ruckelshaus Institute

Jo Albers, Knobloch Chair in Conservation Economics
Maggie Bourque, Academic Programs Coordinator, Assistant Lecturer
Courtney Carlson, Assistant Professor
Kit Freedman, Project and Outreach Coordinator
Mandy Gifford, Administrative Associate
Nyla Hurley, Special Events Coordinator
Nicole Korfanta, Ruckelshaus Institute Director
Melanie Matthews, Academic Advisor
Kimberly Messersmith, Business Manager
Kevin Monteith, Assistant Professor
Fred Ogden, Cline Chair in Engineering
Emilene Ostlind, Communications Coordinator
Steve Smutko, Spicer Chair in Collaborative Practice
Temple Stoellinger, Assistant Professor
Doug Wachob, Academic Programs Director, Interim Dean
Jessica Western, Collaboration Program Director

Supporting partners

This issue of *Western Confluence* is supported by generous contributions from Richard and Mary Lou Taggart, the Walton Family Foundation, the Ordway family, and our dedicated readers.

Contact Us

Western Confluence is published by the Ruckelshaus Institute of Environment and Natural Resources at the University of Wyoming, helping communities solve environmental and natural resource challenges.

uwyo.edu/haub/ruckelshaus-institute

Twice a year, *Western Confluence* magazine brings you on-the-ground, science-based stories about the interdisciplinary, collaborative solutions to our toughest natural resource challenges.

Western Confluence
Ruckelshaus Institute
University of Wyoming
804 E Fremont St
Laramie, WY 82072
(307) 766-2604
editor@westernconfluence.org

EDITOR'S NOTE

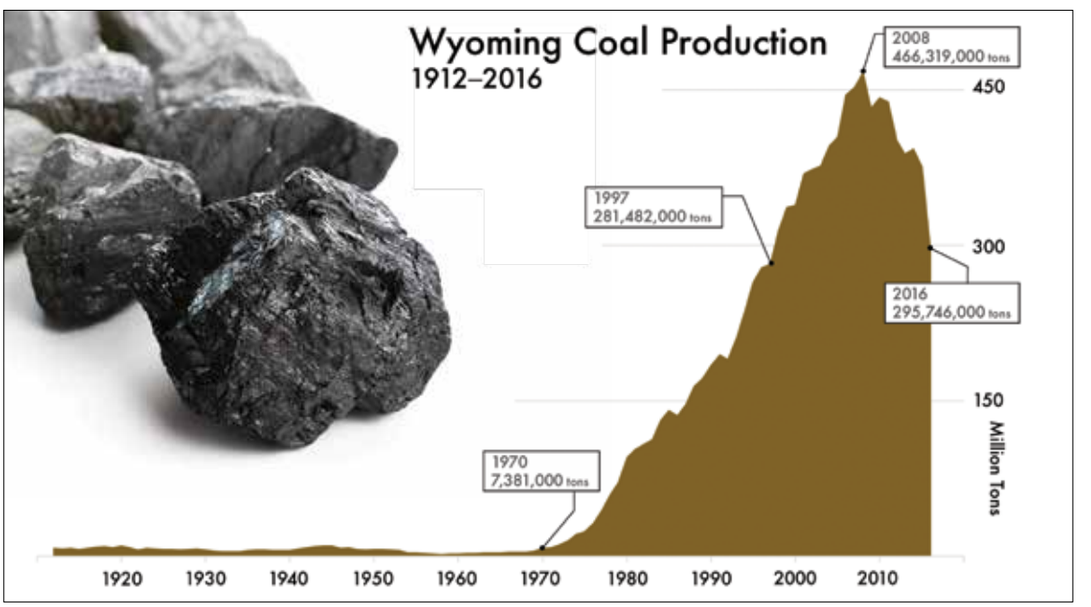
By Emilene Ostlind

Coal powers America. Or at least it has for the last sixty years. For most of the last century, anywhere from 45 to 55 percent of US electricity came from coal. And since the 1990s, about 40 percent of that coal has come from Wyoming's Powder River Basin, home to eight of the country's ten biggest coal mines, including the North Antelope Rochelle Mine, the largest coal mine in the world. In 2008, at the peak of production, dozens of mile-long coal trains left the Powder River Basin every day, headed for power plants in more than 30 states.

Now the country's energy portfolio is shifting. In 2008, US energy demand leveled off and has been mostly flat ever since. And by 2016, only 30 percent of US electricity came from coal, surpassed for the first time by natural gas, which provided 34 percent of the nation's electricity. In 2016 the US produced less coal than any year since 1978. Wyoming's production dropped more than 20 percent from the previous year, sinking to less than 300 million tons for the first time since 1997.

This issue of *Western Confluence*, our energy issue, is motivated by that abrupt shift in the nation's energy portfolio. What's behind these changes, and what will our future energy landscape look like? Coal's decline is driven by a range of factors, from citizens installing increasingly affordable solar power systems on their rooftops, to state officials requiring utilities to replace polluting coal with clean renewables, to federal policies limiting the emissions from coal-fired power plants. Technological advances are bringing down the cost of wind turbines, while a glut of domestic natural gas offers a cheap energy source. These many bottom-up and top-down forces complicate the energy story.

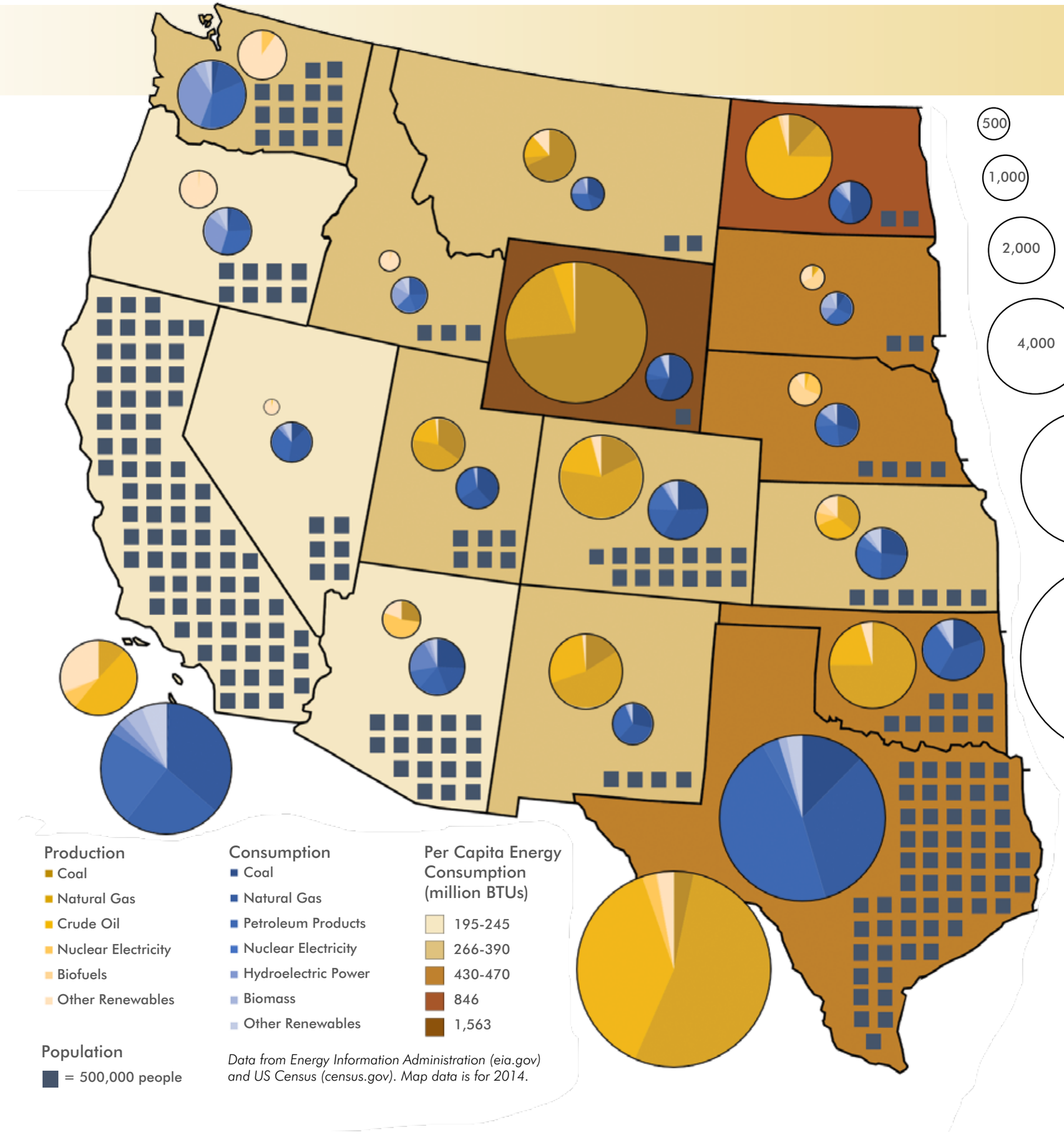
Considering such complexities, this issue has been challenging to put together. Some premises that seemed firm last August when we began working on this issue have turned upside down in the months since. But a few things remain true. States, through their own policies, have a strong say in how energy development moves forward and can drive regional energy trends. And the market is one of the strongest forces shaping the energy landscape. As westerners, it's in our interest to take a clear-eyed view of this shifting energy landscape and try to understand what forms it might take in the coming years and decades. We hope this issue of *Western Confluence* will help you understand our changing energy world.



Data from the Wyoming Mining Association and the Energy Information Administration.

UNIVERSITY OF WYOMING
Ruckelshaus INSTITUTE

CONTENTS


500
1,000
2,000
4,000
Production
Coal
Natural Gas
Crude Oil
Nuclear Electricity
Biofuels
Other Renewables
Consumption
Coal
Natural Gas
Petroleum Products
Nuclear Electricity
Hydroelectric Power
Biomass
Other Renewables
Per Capita Energy Consumption (million BTUs)
195-245
266-390
430-470
846
1,563
Population
= 500,000 people
Data from Energy Information Administration (eia.gov) and US Census (census.gov). Map data is for 2014.

ENERGY IN THE WEST

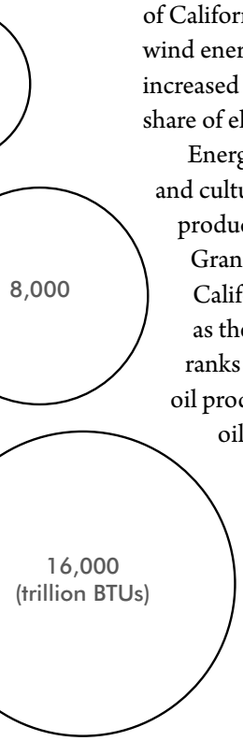
By Emilene Ostlind and Kit Freedman

Over the last quarter century, the western states' energy portfolio has shifted. Coal used to produce far and away the largest share of electricity, but recent advances in hydraulic fracturing and demand for low-carbon fuel have bumped natural gas to first place. For example, over the last ten years Utah replaced nearly a quarter of its coal-fired electricity with natural gas generation and more than half of California's electricity generation comes from natural gas. Similarly, wind energy, now one of the most inexpensive electricity sources, has increased substantially since the early 2000s, surpassing nuclear for its share of electricity generation in the West.

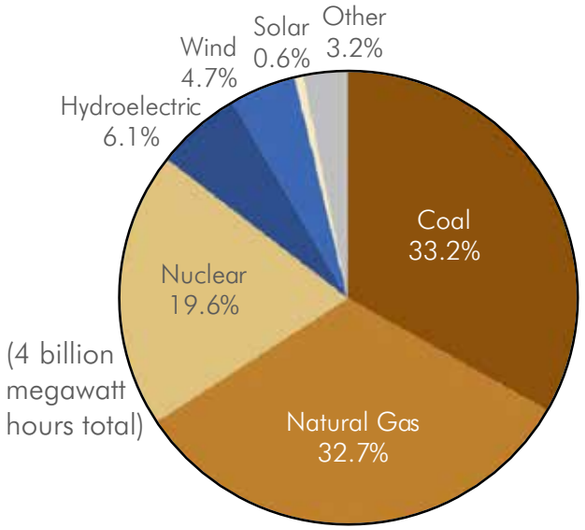
Energy resources match the geology, climates, landscapes, policies, and cultures of the states where they are found. The northwest produces mostly hydroelectric energy, including Washington's Grand Coulee Dam, the country's largest hydroelectric facility. California produces more than four times as much solar energy as the second-ranked state in the nation, Arizona. California also ranks third among states (after Texas and North Dakota) for crude oil production. The Rocky Mountain states produce abundant coal, oil, and natural gas. North Dakota's Bakken oil field is going strong, and Wyoming provides more than 40 percent of US coal. Six western states produce nuclear energy, including Arizona, home to the Palo Verde Nuclear Station, the largest electricity generator of any kind in the nation. Nebraska makes more corn-based ethanol, a biofuel, than any state except Iowa. And Texas produces the most crude oil, natural gas, and wind energy of any state.

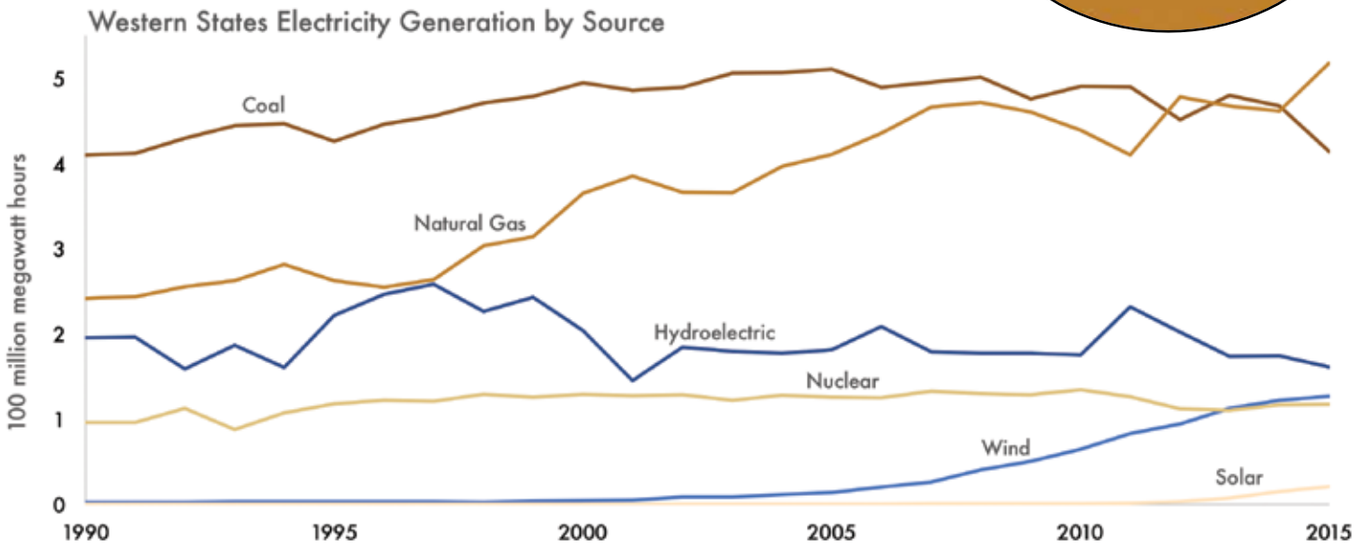
Producing fossil fuels requires a lot of energy, driving up per-capita consumption in some energy exporting states. Energy-intensive industrial processes, long travel distances, severe weather, and a lack of efficiency incentives can explain why states like North Dakota and Wyoming have such high per capita energy consumption. In South Dakota and Nebraska, electricity-hungry crop irrigation increases per capita energy consumption. And in Oklahoma and Texas, the industrial sector, including energy production, uses a lot of energy.

As markets, demands, and policies change, the energy mix, both in the West and on a national scale, will continue to shift in the coming years. How exactly energy resources will fall onto the map remains to be seen.



Total US Electricity Generation by Source, 2015





CARBON CAPTURE

Wyoming could lead the world toward a cleaner energy future

By Emilene Ostlind

This December, five international research teams will converge at the outskirts of Gillette, Wyoming, to compete for a $7.5 million Carbon XPRIZE. The challenge: strip the atmosphere-altering carbon dioxide (or CO_2) out of the exhaust from a coal-fired power plant and convert it into something valuable. The teams propose to make such products as 3D-printed concrete-replacement building material, graphitic nanoparticles, and plastics. Each team will have access to a test bay in the Integrated Test Center, Wyoming's new carbon capture research facility.

The Carbon XPRIZE focuses on "capture," pulling CO_2 out of power plant and industrial facility emissions, and "utilization," finding a commercially economical use for the captured carbon. Turning waste CO_2 into marketable items could develop new industries that eventually keep large quantities of the gas out of the atmosphere. But reducing carbon dioxide emissions enough to address the looming climate crisis, experts around the world agree, will also require carbon "storage." That entails securing captured carbon in geologic formations deep underground.

Separate from and simultaneous with the Carbon XPRIZE competition, experts from the University of Wyoming's Carbon Management Institute are investigating carbon storage. Working with utility representatives, economists, legal scholars, and others, they are designing projects to store at least 50 million tons of carbon dioxide in deep saline aquifers in two different areas in Wyoming. To date no such commercial-scale carbon storage site is ready to accept CO_2 in the United States.

So Wyoming is coming at the carbon challenge from both ends. While the XPRIZE contestants perfect their capture and manufacturing techniques at the Integrated Test Center, a separate group of researchers in Wyoming will tackle the storage problem. Both endeavors are key to the global race to meet climate mitigation targets.

≈

Carbon capture may seem like a last-ditch effort to rescue fossil fuels in a carbon-constrained world. It is expensive and energy intensive. But abandoning carbon-emitting fossil fuels all of a sudden would be more expensive if not impossible, according to expert analyses. The Intergovernmental Panel on Climate Change found that limiting atmospheric carbon dioxide to 450 parts per million, a widely accepted target meant to keep planetary warming under 2 degrees centigrade, would be more than twice as costly without carbon capture and storage as with. To achieve the 2-degree target, the International Energy Agency reports that 104 gigatons of carbon dioxide, or a sixth of all emission reductions worldwide, need to be stored in geologic formations by 2050. Carbon capture and storage buys time to meet the world's growing demand for energy with clean sources by letting us burn coal and natural gas for a while longer, and it will be one critical strategy if we are to put a damper on climate change.

Carbon capture, transport, and injection has been in use for decades in various forms, but meeting climate mitigation targets will require perfecting the technology, bringing the cost down, constructing CO_2 transport networks, and sorting out the technical, social, and legal logistics of geologic storage. Over the last decade, the US government has invested over $5 billion toward solving these challenges, with substantial matches from private industry. And the work is ongoing.

Last fall, some of that federal investment came to the University of Wyoming. Kipp Coddington, director of the UW Carbon Management Institute, is principal investigator on two Wyoming storage projects. With $2.4 million from the Department of Energy, the charge is to draw up blueprints for economically viable, commercial-scale carbon storage. One project targets deep saline aquifers in the Powder River Basin near the Integrated Test Center, and the other will focus on the Rock Springs Uplift, a well-studied geologic structure in southwest Wyoming. Over the next year and a half, Coddington and his team members will outline where the CO_2 will come from, how it will be transported, where to store it, and how to ensure it won't escape once underground. They'll make a plan to secure the necessary agreements with everyone from electricity providers, to landowners, to state regulators, and others. And they'll show how to pay for the carbon storage.

No large-scale carbon storage projects exist yet in the United States. "I hope that we will be on the pioneering side of that in Wyoming," says Tara Righetti, School of Energy Resources assistant professor of law and a member of the interdisciplinary team. "Personally, I'm really excited to try to write the first injection lease." All the pieces seem to be in place for Wyoming to blaze the trail.

For starters, Wyoming has ample anthropogenic carbon sources. One of the projects has its sights on emissions from the two-gigawatt coal-fired Jim Bridger Power Plant, which pumps out about 15 million tons of CO_2 every year outside Rock

Springs. The other is looking at the Dry Fork Station, the power plant that is home to the Integrated Test Center.

Then, Wyoming already has about 900 miles of CO_2 pipelines, with another 200 miles planned. While those are designed for enhanced oil recovery (a process of injecting CO_2 into flagging oil fields, which loosens the oil's hold on the strata and pushes it toward production wells), in the future, this pipeline network could help carry anthropogenic CO_2 emissions to geologic storage sites.

Following a long history of oil and gas mining in the state, Wyoming has extensive data from and expertise about the state's geologic formations. Plus, the Carbon Management Institute already studied the storage potential of saline aquifers in the Rock Springs Uplift and determined they could hold as much as 14–17 gigatons of CO_2, equal to 1,000 years of emissions from the Jim Bridger Power Plant or about seven to nine years of emissions from the entire US power industry.

Another advantage, says Scott Quillinan, Carbon Management Institute senior hydrogeologist and a team member, is that "bringing in a drill rig isn't that big a deal in Wyoming. We've done it before. There's a skilled workforce here to do it."

Furthermore, in 2008 Wyoming was the first US state to adopt laws for carbon capture and storage, clarifying ownership of the underground cavities that will hold the CO_2, among other aspects of the process.

"We have the support of the governor and the legislature and we have industry in place," adds Righetti. All these factors align to give the team confidence that they will be able to present a sound plan to the Department of Energy, and hopefully advance to the next round of funding, a lengthier phase to put the project into motion. If Energy Department priorities and budgets remain intact over the coming years, the agency aims to have four US storage sites locking up carbon by the millions of tons within the decade.

"We really want one of these final projects to be up and running here in 2025," says Coddington.

While the team has great confidence in the technical feasibility and geologic conditions, "I think the economics of these projects are going to be challenging," Coddington says. Carbon pricing, a fee for emitting carbon pollution, has been proposed in Congress several times but never passed. Such a policy would provide the necessary economic incentive to store carbon. But in the absence of carbon pricing it's harder to make the numbers pencil out.

"When you are just injecting CO_2 into saline storage there isn't a business case there," Coddington points out. "That's just a deadweight loss." He and his team may consider solutions such as selling some of the captured CO_2 for enhanced oil recovery or other industrial processes, or getting electricity customers in places like California to help pay for the low-carbon energy.

At $60-90 per ton of CO_2, capture is the most expensive part of the process. Transportation and injection add about $15 per ton. Technology costs tend to come down over time, and the Department of Energy's goal is to reduce capture costs to $30-40 per ton. Another place to seek efficiencies is in energy consumption. The "parasitic load," as it is termed, to separate carbon from flue gas and compress it for pipeline transport, can eat up as much as 40 percent of a power plant's energy.

Joe Riis/USFS

Reducing carbon capture's cost and energy needs will require more research and development. That's where the Integrated Test Center comes in. It's a place for researchers to scale up new technologies that have gone through laboratory testing, but which aren't yet ready to implement at commercial scale. The Integrated Test Center is only the second US facility, after the Department of Energy's National Carbon Capture Center in Alabama, where researchers can test carbon capture technologies with real power plant emissions.

Over the nine-month competition period, the Carbon XPRIZE team that captures the greatest percentage of CO_2 from the Integrated Test Center's flue gas ducts while producing the most valuable product will win the $7.5 million cash purse. That will mean finding an efficient, cost-effective means of capture. And these teams will be just the first of many tenants studying carbon capture at the Integrated Test Center, so if one of them doesn't have a breakthrough, perhaps a future tenant will. That would be good both for the race to reduce global carbon emissions and for Wyoming.

"As we look toward a low-carbon energy future, developing those technologies is key to expanding and diversifying the state's economy," says Jason Begger, executive director of the Wyoming Infrastructure Authority which oversees the facility. The state of Wyoming contributed $15 million toward the Integrated Test Center's $20 million price tag in hopes the investment will pay off by helping keep the coal economy viable and by enticing entrepreneurs who develop new technologies to set up their companies in nearby Gillette. As carbon capture research advances alongside carbon storage, Wyoming may lead the world toward a cleaner energy future."If we can't make it work in Wyoming, I don't think it will work anywhere," Quillinan says. "All the pieces are here that are needed to make it work."

***Emilene Ostlind** edits* Western Confluence *magazine and writes about natural resource issues in the West.*

SCENARIOS
P·L·A·N·N·I·N·G

An oil major considers possible futures to prepare for a changing world

By Case Button

Royal Dutch Shell's primary business is the discovery, extraction, refinement, transportation, marketing, and selling of oil. It produces three million barrels of black gold each day and owns over 300 companies operating in over 100 countries, making it the second largest non-state-owned oil company in the world. When burned, its viscous moneymaker emits carbon dioxide, one of the leading causes of climate change.

So why would Shell join five other "oil majors" in a letter asking governments around the world to put a price on carbon and address climate change, the "critical challenge for our world"?

One explanation is "scenario planning"—a strategy for peering into possible future scenarios and preparing for unseen, unexpected, and sometimes unwanted changes.

≈

In the late 60s, Shell Executive Pierre Wack and his colleague Ted Newland set out to engage the company's leadership in creative thinking. Among the biggest oil companies, known as the "seven sisters," Forbes had dubbed Shell "the ugly sister" for its weak standing. Wack and Newland believed shifting how Shell leaders thought about the future would make the company stronger. They turned to scenario planning, a business tool designed to "go beyond conventional energy outlooks and consider long-term trends in economics, energy supply and demand, geopolitical shifts, and social change," according to Jeremy Bentham, head of Scenarios, Strategy, and Business Development at Shell today.

Wack theorized that creativity could be institutionalized in corporate planning. Building on traditional scenario planning and military game theories, Newland and Wack divided visions for the future into two groups: the known and the unknowable. They wanted business leaders to not only consider what was probable, but also be prepared for anything possible. "I had the feeling," said Wack, "of hunting in a pack of wolves, being the eyes of the pack, and sending signals back to the rest."

To prepare business leaders for the unexpected and unknowable futures, he and Newland spoke openly to executives about the company's hubris, and unearthed assumptions that would otherwise lie dormant. They analyzed data, but they also looked at possible global trends that most others ignored. They created a culture around questioning and exploring every assumption, resulting in several scenarios that discouraged the magnetic pull of the company's ideal version of the future. Wack called

it "the gentle art of re-perceiving."

In 1972, Wack presented a report to Shell's managing directors—recalled by those in the room as an "enthralling three-hour performance"— in which he outlined six scenarios depicted as a river forking into two streams, each dividing further into three tributaries. In one of those scenarios, he anticipated skyrocketing oil prices. He groomed Shell's leadership to take immediate advantage of such a situation.

Then came 1973. The price of crude oil jumped from about $2.50 a barrel to $11 amid global oil shortages, sparking an energy crisis that left most oil companies scrambling to react. Some collapsed entirely. Meanwhile, Shell's leaders swiftly diversified into nuclear energy and cut costs that had risen dramatically through the frenzied growth of the 50s and 60s. Thanks to Wack and Newland's scenario planning, they knew the waterfall was coming before others felt the currents. By the end of the decade Shell was no longer the "ugly sister."

"Forecasting produces answers, but scenario-based planning had made people ask the crucial questions," wrote Kees van der Heijden, former Chief of Shell's Scenario Planning. Or, as Newland put it, the scenarios, "create[d] a culture where you could ask anyone a question, and the answer would need to be contextual. Answering 'Because I'm the boss' or 'Because the business case is positive' was out-of-bounds."

The scenarios allowed Shell to see realities that might otherwise be overlooked. Over the years, in part as a result of scenario planning, Shell has been stronger in its oil forecasts. It weathered, better than most, not only the 1973 energy crisis, but also the price shock of 1979, the crumbling oil market of 1986, the collapse of the

POLICY BOX

THE CLEAN POWER PLAN

By Emilene Ostlind

When Congress failed to enact legislation to address climate change, President Obama vowed to take action himself. "No challenge poses a greater threat to our children, our planet, and future generations," he said. In August 2015 Obama and the Environmental Protection Agency issued the Clean Power Plan, a series of regulations under the Clean Air Act that would reduce carbon dioxide emissions from power plants by about a third by the year 2030.

Electricity generation is responsible for about 37 percent of carbon emissions in the United States, according to the US Energy Information Administration. The CPP would shutter hundreds of existing coal-fired power plants and replace them with cleaner power sources. Obama used the CPP to leverage international agreement on the Paris Climate Accord. Supporters call it the most significant step ever taken to reduce climate change, while critics call it an unlawful overstep, misuse of the Clean Air Act, expensive, and a threat to states.

Upon release of the CPP, several industry groups and 28 states including Wyoming sued to stop it, and in February 2016, the Supreme Court blocked implementation of the regulations while the lawsuit plays out. In September 2016, the DC District Court heard oral arguments on the case, and it has yet to make a decision. Then, in November 2016, Donald Trump, who has vowed to do away with the Environmental Protection Agency, became president-elect of the United States. He nominated Scott Pruitt, Oklahoma's attorney general, to head the EPA. Pruitt has denied anthropogenic climate change, is a lead architect of the legal battle against the CPP, and has strongly opposed a range of environmental regulations.

Under a Trump administration, the CPP could be weakened or eliminated by the courts, by the EPA, or by Congress. The DC District Court could side with the litigants and determine that the rule is illegal. If the District Court upholds the rule, it could be appealed to the Supreme Court, in which case Trump's appointee to the vacant justice seat could sway the outcome. Meanwhile, the Trump administration could voluntarily remand the CPP back to the EPA, which, under Pruitt's oversight, would undergo a year-long process to revise, and presumably weaken, the rule. Furthermore, the Republican-led Congress could override the CPP by passing a bill prohibiting the EPA from regulating carbon dioxide emissions from the power industry.

Soviet Union, and the volatility of the Middle East.

Today, Shell's scenario planning team is issuing a different warning: climate change is real, and we have to do something about it. Shell's 2013 *New Lens Scenario* envisioned a challenging but "achievable" roadmap: sustainable economic growth coupled with net-zero emissions by the end of the 21st century.

The scenarios explore two paths: one that builds quickly and efficiently on natural gas as a bridge fuel while other alternatives develop, and the other building on the idea that solar becomes the top energy source over a longer timeframe during which climate change advances more rapidly. Both have different outcomes based on choices made by governments, businesses, and individuals over the short and long term. Shell's report also suggests that carbon capture and sequestration (an expensive technology which hasn't been developed on a commercial scale) will play a large role.

Striving for a net-zero emissions world may seem surprising from a company that has been in the business of carbon for over 100 years, whose main product releases billions of pounds of climate-change-causing carbon dioxide each year. What may be even more surprising is that Shell isn't the only one envisioning a low carbon future. A letter to the UN from six "oil majors"—BG Group, BP, Eni, Royal Dutch Shell, Statoil, and Total—stated, "The need to cut emissions is so essential that we have to pursue all options to lower carbon while providing the energy the world needs to meet demand from a growing population..."

So what gives? One answer may come from a line later in that same letter. "[N]atural gas can help deliver this."

Shell, like many oil companies, is vertically integrated, connected to the entire supply chain for both natural gas and oil. Natural gas has been called a "bridge fuel," buying oil companies time to adapt because when burned it emits half as much carbon dioxide as oil. Unlike other fossil fuel industries such as coal, the oil business could actually benefit from a tax on carbon if it increases demand for low-carbon natural gas, which they can provide. Big oil companies know this. And they feel the headwinds of the Paris Accord, public opinion, and scientific evidence.

Reaction to the report has been mixed, and there have been some surprising advocates. For the first time, Shell's leadership said the scenario, which aimed to stay within a global temperature rise of four to six degrees Celsius, didn't go far enough. Two years after the report came out, Shell's shareholders unanimously voted to force Shell to examine the possibility of keeping the increase of average global temperatures below two degrees Celsius, the goal of the Paris Accord. As a result, the company wrote an addendum to the 2013 scenario report.

And Shell has seemingly begun to adapt, establishing a company division called "New Energies" to invest in renewable and low-carbon power, combining its existing hydrogen, electrical, and biofuels division with wind power. But its annual spending on these low-carbon sources, mostly for research and development, is a small percentage ($200 million) of the $30 billion Shell invests in oil and gas research and development.

Shell's business model continues to rely primarily on extracting huge amounts of fossil fuels, with no signs of slowing. Crude oil production is by far its major revenue stream. In its 2013 report Shell states, "we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10–20 years."

Still, Shell's long-term scenarios acknowledge and plan for a changing climate. Its leaders and board members, armed with scenarios, are embracing a changing reality, so if and when a carbon tax does take hold, they will be ready.

Case Button *has covered policy issues for four years as a freelance journalist and speechwriter.*

A "JUST TRANSITION" FOR FOSSIL FUEL WORKERS

The search for a jobs-positive shift to clean energy

By Nathan C. Martin

Nearly 500 Wyoming coal miners were laid off last spring, and in the past two years roughly 5,400 oilfield workers lost their jobs in the state. In 2015, Wyoming saw the highest unemployment spike in the nation. Fossil fuel industries here support a whole host of related businesses that provide supply, repair, transportation, legal, accounting, and other services to mining operations. Those suffered dramatically, too. The subsequent drop in tax revenue led to a budget shortfall of roughly $150 million this past fiscal year and deep cuts to public services statewide.

Wyoming at present is experiencing a grim case of *déjà vu*, thrust by low commodity prices into an economic slump after a decade of good times. Previous busts have been temporary, and workers needed only to wait until energy prices rebounded for the industries to right themselves and offer more jobs. But the current situation is prompting economists, government officials, and workers alike to wonder if we might be catching a glimpse of Wyoming's future in a fossil fuel-free world.

"This storm looks long, like a structural change, not just a cyclical downturn," says Robert Godby, director of the Center for Energy Economics and Public Policy at the University of Wyoming.

Some in Wyoming look forward with hope to Donald Trump's presidency, since he made sweeping promises about saving the coal industry. But market forces—not regulation—are largely responsible for the downturns in the oil, gas, and coal industries.

"If there's any culprit in terms of coal's woes right now, it's natural gas, and has been since 2008," says Godby. Fracking, which ramped up nationwide around 2008, enabled companies to overproduce and thus create a supply glut of oil and gas, deflating fossil fuel prices across the board and hitting coal particularly hard.

Regardless, Wyoming's economy is famously homogenous. Mining—mostly for oil, gas, and coal—employs more than ten percent of the state's total workforce at salaries far higher than the statewide average. A larger percentage of Wyoming's population works in fossil fuels than does that of any other state. Wyoming's second largest industry, tourism, offers mostly low-paying service jobs. Scattershot opportunities exist for laid-off miners in smaller local industries like construction, but options for good work are widely limited. It is easy to understand why, from the vantage of Wyoming, a world transitioning away from fossil fuels appears a foreboding landscape—one in which fossil fuel workers bear the brunt of a societal shift.

Amidst the debates over climate change taking place worldwide, voices calling for a "just transition" are becoming louder and more highly regarded. The notion of a "just transition" originated in the 1990s among labor groups whose members worked with toxic chemicals that government regulations were phasing out. It evolved in the era of global warming to describe a transition to renewable energy that does as little harm as possible to workers—in fossil fuel industries and otherwise.

Jeremy Brecher said climate activists and labor organizers are working more closely than ever to protect jobs and slow global warming at the same time. Brecher is the co-founder of the Labor Network for Sustainability, a coalition formed in 2009 whose notion of sustainability relates not only to climate change, but to employment and social justice as well. Brecher noted the International Association of Machinists, whose membership includes railroad workers who haul coal to West Coast seaports, passed a major resolution in September recognizing the union's need to support climate action. In 2015, the International Trade Union Confederation, which represents more than 180 million workers in 162 countries, hosted a summit on global warming titled "No Jobs on a Dead Planet." And even though national labor unions in the United States have been reluctant to support many measures to fight climate change because of a perceived jobs risk, activist stirrings among local chapters indicate a rank-and-file willingness to advocate for climate justice. For instance, although five of the country's largest unions officially came out in favor of the Dakota Access Pipeline, in October a sizeable contingent of union workers set up camp alongside Native American water protectors on the Standing Rock reservation in North Dakota to help stop its construction.

"It just shows that people are becoming aware that this threat is so serious that we have to act on it, even if that makes some economic problems for us," Brecher said. "But we have to address those economic problems, as well, and find a worker-friendly way to move to fossil-free energy."

According to a Labor Network for Sustainability study, the switch to renewable energy has the potential to create hundreds of thousands of jobs nationwide, mostly in manufacturing and construction. An ideal "just transition" might fill these positions across the country with laid-off Wyoming miners.

"The overall effect [of a switch to renewable energy] is very jobs-positive—numerous other studies have come to the same conclusion," Brecher said. "A lot of people who work in Western coal mines have the skills of construction workers, like the capacity to operate big machinery. There will be a lot of jobs in building the clean energy economy for people with those skills."

But while some of those jobs already exist, most do not. And while some of them will exist in Wyoming, many will require displacement. Crews broke ground in September in the southern part of the state on what will be the largest wind farm in the world, but the construction will mostly be executed by specialists not likely from Wyoming or inclined to stick around after the wind farm is complete. The state did hardly anything to attract related industry that would provide high-paying jobs in the long term, such as turbine manufacturing. While building a renewable energy infrastructure will be jobs-positive on a national and global scale, little at this point indicates Wyoming will take advantage of the opportunity.

In the absence of readymade jobs to fill, Brecher said a support system should be put in place to buoy workers set adrift by climate policies. The best model, he said, is the GI Bill of Rights that helped soldiers returning from World War II re-enter the working world. Their benefits included access to a full education as well as low-interest home mortgages and business loans.

"We need something that makes that kind of boost available to anybody whose job is lost as a result of policies that are necessary for the future of the world," he said.

Last year, as the coal industry buckled, President Obama unveiled the POWER Plus Program, which allocates money for struggling coal communities. It remains to be seen whether President Trump will push for federal funds to help these communities and workers, whose recovery looks difficult even without regulations. But Wyoming officials seem eager to find a market solution to fossil fuel's woes, even if the market caused those woes in the first place.

Jeremiah Rieman, natural resources policy director for Wyoming Governor Matt Mead, scoffed at Obama's programs. First, he argued, any measure to abandon coal would be "a troubling, shortsighted move"—a dig at Obama's Clean Power Plan, which Trump has promised to scrap. Furthermore, Rieman said, Obama's POWER Plus program is unfair to Wyoming because it relies in significant part on money the state's coal operators have paid into the Abandoned Mine Lands Fund—allocations that would normally return directly to Wyoming. Instead, the lion's share of POWER Plus money is slated to go to eastern and Appalachian states like Virginia and Kentucky, which are also facing a coal crunch.

"In the last POWER proposal I saw, very little would be available for Western states," Rieman said. "At the same time Wyoming is being impacted by these [climate] proposals, there's very little to suggest that we would benefit from the programs that are being put forward."

Godby, the economist, said instead of using AML funds, the best way to financially support workers and communities impacted by climate policies would be a national carbon tax. Recent reports from the Brookings Institute note such a tax could, conservatively, generate up to $1 trillion in revenue in the span of a decade.

"The big benefit of a carbon tax is that it raises revenue to cover the transition costs of imposing regulation—to at least do something to offset some of those effects, whether it's for training or economic development," Godby said. "With any other approach—including the Clean Power Plan—you're going to have to generate additional revenue somewhere else or reallocate expenditures to help the transition."

Compared to the Clean Power Plan, which clocks in at 1,560 pages and requires massive amounts of centralized oversight, a carbon tax would be simple, transparent, and cheap to implement, Godby said. But imposing such a tax would require an act of Congress, and in this political climate, Godby said, "'tax' is a four-letter word. People hate taxes. We should probably start by renaming it. Maybe call it a 'fee.'"

> "A lot of people who work in Western coal mines have the skills of construction workers, like the capacity to operate big machinery. There will be a lot of jobs in building the clean energy economy for people with those skills."
>
> – Jeremy Brecher, Labor Network for Sustainability

Rieman said coal is already considerably taxed, at an effective rate of 39 percent including royalties and fees, and if anything, taxes should be decreased because they're overburdening the industry.

"It's better to invest in miners and mining and continuing to mine and investing in technology as a solution, rather than taxing these resources out of use," he said.

Elsewhere in the state government, members of the Wyoming Business Council are working to expand the economy beyond just mining. Touting the nation's friendliest tax policies, the council's ten-year plan calls for courting companies to expand five target industries: manufacturing, advanced conversion technology (clean coal), data centers, logistics and distribution (shipping), and lifestyle entrepreneurs (which the Northeast

Wyoming Growth Alliance describes as "the telecommuter who works via wifi on her front porch; the fly-fishing guide who schedules appointments online; the potter or the writer who creates in a back-yard studio"). Spokesperson Ron Gullberg said the council is beefing up its outreach, redesigning its website to present a more attractive digital front end, and developing a "business ambassadors" program to generate leads. It recently entered into a partnership with XPRIZE, a $20 million global competition to find ways to transform carbon emissions into saleable products (the winner will be the first tenant of the new Wyoming Integrated Test Center, a new research hub studying "clean coal" technology).

"A lot of what might seem like little things are very important," Gullberg said. "We're getting our storytelling up there, getting word out about infrastructure and Wyoming's business advantages—the low cost of doing business here, with no corporate or income taxes."

One major tool for spurring development, however, has been lately diminished: state funds. The Wyoming Business Council relies heavily on its Business Ready Community Grant program to incentivize companies to choose Wyoming. In recent years, for instance, the council awarded farming technology upstart Bright AgroTech $2.85 million for a new headquarters, it granted tech firm UL $3.3 million for a new facility, and firearms accessories manufacturer HiViz received $2.9 million to relocate from Colorado. But statewide funding cuts did not spare the council. Its grant program was slashed roughly 30 percent from the prior biennium, down to $38.5 million for 2017–2018. Another $20 million pool the council used for one-time business funding was eliminated altogether.

Gullberg said the state-level belt-tightening made some members of the council eager to explore options for federal funding, like those available from Obama's POWER program. Wyoming faces difficulties attracting businesses because it's such a small market, not densely populated, and it competes with regional urban hubs like Denver and Salt Lake City that offer firms access to more economic activity. Being able to offer a company $3 million for shiny new headquarters definitely helps.

But Dave Spencer, director of the Wyoming Business Council's northeast region, took one taste of Obama's program and soured to it. After learning of POWER in 2015, Spencer and his colleagues in the region crafted a set of proposals for the Economic Development Agency, which oversees POWER funding. These included studies related to tourism, plastics manufacturing, and a research facility in the area's small towns.

"We put together a bunch of projects, but the EDA kind of turned their nose up at them," Spencer said. "Their requirements are so stringent that they're really hard to work with, and we just didn't feel like it was worth pursuing."

Among the POWER plan's requirements for funding is a local match—something the Wyoming Business Council would need to provide, since, Spencer said, "None of these communities have money for a match."

But Spencer's experience speaks to deeper divisions between the federal government and conservative, fossil fuel producing states. It suggests the movement for a "just transition" has a long way to go before everyone is convinced that a big pot of government money—whether it comes from AML funds, a carbon tax, or elsewhere—is going to provide a smooth ride to the New Energy Future.

"The state's not in great shape financially, so any outside help we could get might be welcome," Spencer said. "But our typical experience with using those kinds of funds on state projects is that it adds a level of complexity to the point that you wonder whether it was worth it or not. They're not easy to work with. Maybe we're just too independent out here or something."

Nathan C. Martin *is a freelance writer from Wyoming.*

Q&A

The Most Complicated Machine Ever Built

How to modernize the power grid

By Sarah Jane Keller

Renewable energy is on the rise in the western United States, and the world. That trend needs to continue if we're to meet the emissions reduction targets that most climate scientists deem necessary for staving off catastrophic climate change. But according to Carl Zichella, who directs the Natural Resource Defense Council's work on western energy transmission, we can't get there with the outdated grid we have now.

Today, the energy grid in the western United States is run by 38 different entities called "balancing area authorities," many of which are operated by a single utility. It's hard for these disjointed segments of the grid to share renewable energy. A single west-wide system would be more reliable and make better use of renewable energy, helping reduce greenhouse gas emissions. According to Zichella, who has been working on grid policy since 2008, the West already has a model for this more modern, unified grid. It's the California Independent System Operator (CAISO), a third-party, federally regulated, nonprofit organization that coordinates the many electricity producers and utilities in California's energy system. Zichella and others have been working on policies that would expand the CAISO model throughout the West, creating a grid with more capacity for renewable resources.

Western Confluence spoke with Zichella about his ideas for updating the grid to keep pace with the West's changing energy landscape.

Megan Krause/NRDC

Carl Zichella

Western Confluence: How does the energy grid in the western US work today?

Carl Zichella: The grid is the most complicated machine we've ever built. It's gigantic, it is complex, and to get the most efficient use out of the system we have to use it in the most coordinated way that we can.

In the West today our grid is broken up into all these small, little areas that really use the system pretty wastefully and require us to build duplicative resources like power plants we may not need. That's because each of those 38 areas is responsible for balancing demand and generation within their footprints.

In other parts of the country there are entities called independent system operators that run large portions of the regional grid. The independent system operator is like the traffic cop of the system. But in the western United States there aren't these independent system operators, with the exception of California. It makes it hard to take advantage of renewable energy resources.

WC: Why is that?

CZ: Renewable resources are variable resources that don't always operate 24/7. But in a big footprint across the western US, the wind is always blowing someplace. So [with a better integrated grid, one managed by a large independent system operator] we could take solar power from California and send it to Oregon … We could take the wind energy from Wyoming and use it to operate any hours that wind power in Oregon's Columbia Gorge isn't operating, for example.

We would have the ability to use renewable energy resources just as reliably as we would a gas or coal plant, as long as we could use them over a big footprint. But we can't do that in the West today because our grid is broken up into all these small, little areas. So it's very wasteful.

There have been numerous studies done about how best to clean up the grid, to use more and more renewable energy resources. And all of those studies point to better system coordination as being a key feature of being able to bring renewable energy resources in.

WC: What is the path for turning those 38 entities into one operating system overseeing the western grid?

CZ: So we already have this nucleus around which we can build the grid of the future in the west.

You start by expanding the independent system operator in California. Then, if the utility that serves Utah, Wyoming, Oregon, Washington, and a little tiny part of California, joins the independent system operator, it opens up the grid. Then other utilities gradually join the independent system operator.

The utilities will form a regional market, where they're using the most efficient resources first and using the least efficient and most polluting resources less and less. You can take advantage of the

resources that are operating in any part of the system to support the rest of the grid. That's not possible in a system that's highly Balkanized and fragmented into these many different pieces.

WC: Are there concerns about changing the grid system?

CZ: Yeah, I think whenever you make a major change like this there's a lot of resistance. Some states have built up their economies around mining and burning coal. It's a very tough decision for Wyoming, for example, that has 70 percent of its state revenues coming from levies on extractive industries. When those industries begin to vanish, well of course there's going to be some resistance.

So we have to help every participant in the western electrical system and economy be able to recognize and realize benefits from the change. And we can do that. But there's going to be some pain. You're losing thousands of coal mining jobs, for example, that's not an easy thing to replace.

WC: What can people do if they want to see a more coordinated grid?

CZ: They can make clear to their state representatives and their utilities that they want clean energy, that they want a more efficient grid, that they want to stop wasting resources and money on a system that is quickly becoming outdated, that we need to modernize the way that we build, plan and operate the system.

The decisions people make about how they use energy and what kind of energy they use are very critical to this. That can help us make the transition more cost effective too, whether it's by putting solar panels on their house, or insisting that the utilities invest in renewable energy.

WC: What's at stake if we continue to use the current grid system?

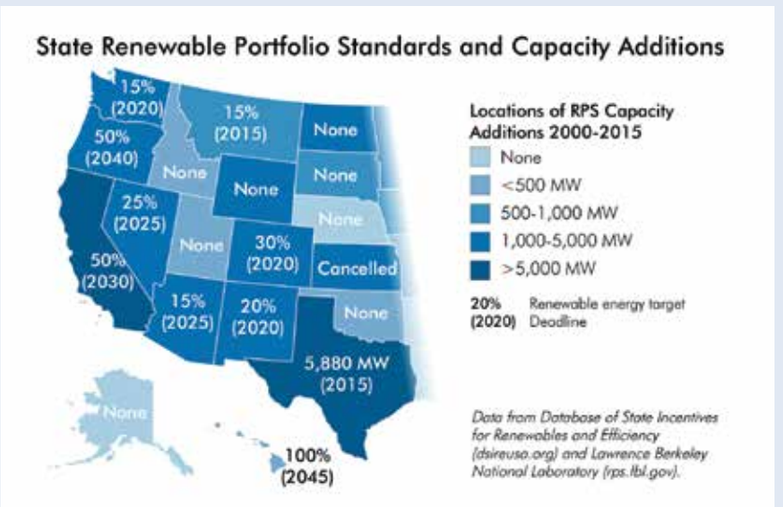
CZ: Well, what's at stake is we don't meet the goal of an 80 percent reduction in greenhouse house gas emissions worldwide by 2050, which is what the Natural Resources Defense Council and other groups, including the Intergovernmental Panel on Climate Change are calling for. And if we don't meet those goals then we have a very grim prospect ahead of us. We're already seeing climate impacts across the western United States like the extended droughts that we've been seeing in the southwestern US and in California, the unusual weather events that we've encountered across the western United States. That has implications for fish, for wildlife, for cities, for agriculture, for every single thing that we touch in our lives.

Sarah Jane Keller *is a freelance science and environmental journalist based in Bozeman, Montana. Find more of her work at sjanekeller.com.*

POLICY BOX

RENEWABLE PORTFOLIO STANDARDS

By Lawrence Wolfe and Emilene Ostlind



Several states have implemented Renewable Portfolio Standards in an effort to cut greenhouse gas emissions from the electricity sector. An RPS sets a percentage of the overall power consumed in a state that must come from renewable sources by a certain year. For example, New Mexico's RPS is for 20 percent renewable energy from utilities by 2020 and Montana has already achieved its RPS of 15 percent renewable energy from utilities by 2015. Some states like Colorado have different standards for utilities, municipalities, and electricity cooperatives (30 percent, 10 percent, and 20 percent by 2020 respectively). Hawaii has the most aggressive RPS at 100 percent by 2045. As of 2016, 29 states, three territories, and Washington, DC, had RPSs.

The goal is to replace high-carbon-emitting electricity generation such as coal-fired power with cleaner energy sources, especially wind and solar. States enforce RPSs in different ways. In some states, if a utility doesn't sell enough qualifying renewable energy to meet the RPS's target, it pays a fine relative to the number of megawatts by which it fell short.

So how well do they work? Economists and policy analysts have determined that RPSs do result in replacing greenhouse-gas-emitting power generation with cleaner sources. About 60 percent of the 100 gigawatts of new non-hydro renewable energy generation capacity that has come online since 2000 fulfills RPS obligations. In 2013, renewable energy sources under RPSs reduced greenhouse gas emissions by an estimated 59 million metric tons of carbon dioxide equivalent, according to the National Renewable Energy Lab and Berkeley National Laboratory.

While RPSs do effectively clean up power generation, it doesn't come for free. The Berkeley Lab estimates that in 2014, RPS compliance cost $2.6 billion above what energy costs would have been without the renewable requirements. That sounds like a lot, but it averaged to less than 2 percent of electricity customers' bills.

States adjust their RPSs for many reasons: to improve how they operate, increase the future renewable targets, require more or less of certain kinds of renewable energy, or to respond to changing politics. For example, in 2015 the California legislature upped the state's renewable target from 33 percent by 2020 to 50 percent by 2030. States can also repeal their RPSs. Kansas demoted its RPS to a voluntary goal after its legislature flipped from mostly democrats to majority republicans in 2015. (Oddly, Kansas had already surpassed the amount of renewable energy required by its RPS, so repealing the law didn't change the state's energy trajectory.)

Wyoming does not have an RPS, but because it exports so much energy, other states' RPSs influence Wyoming's energy portfolio. Wyoming already generates more than a gigawatt (1,000 megawatts) of wind energy that helps states to the south and west meet their RPSs. As states like California and Colorado strive to achieve the escalating targets of their ambitious RPSs while meeting their citizens' growing energy demands, they may look to Wyoming's wind as a source of clean electricity. But that will require overcoming barriers such as national and state politics and the huge cost and general unpopularity of interstate transmission lines.

TURBINES ON THE HORIZON

How the western grid could unleash Wyoming wind energy, for better or worse

Emilene Ostlind

By Nicole Korfanta

California and Wyoming make strange bedfellows, but when it comes to sharing electricity, the two states have been flirting. Wyoming has the reliable, renewable wind energy that California needs. California has the energy customers that Wyoming wind developers are looking for. But while their first date—a foray into a shared electricity market—is going well, the two states are wary of one another. California worries about Wyoming's less-green electrons and the loss of new renewable energy jobs. Wyoming chafes under California's oversight of a shared electricity grid and the prospect of more turbines on the horizon. Popular wisdom holds that Wyoming has little to gain from wind farms that mar the horizon for the benefit of California consumers.

But University of Wyoming research shows something else—Wyoming stands to gain a lot from harnessing its wind potential. Sure, more wind farms in Wyoming would help California meet its renewable energy requirements, and save California money in the process. But studies show that wind could be a moneymaker in Wyoming too, enough to help diversify Wyoming's struggling economy when there are few new revenue sources. Those findings come at a critical time, when the impediments to exporting wind-generated electricity are beginning to abate: the price of wind development has dropped, the demand for clean energy is high, and a bigger electricity grid is in the works. Wyoming could become a major renewable energy player in the western US.

But first it has a choice to make. Will Wyoming court California's wind market or send it packing? If the financial benefits of partnering with California outweigh the downsides, a marriage could spawn new wind farms on the Wyoming landscape.

WYOMING'S WIND IN DEMAND

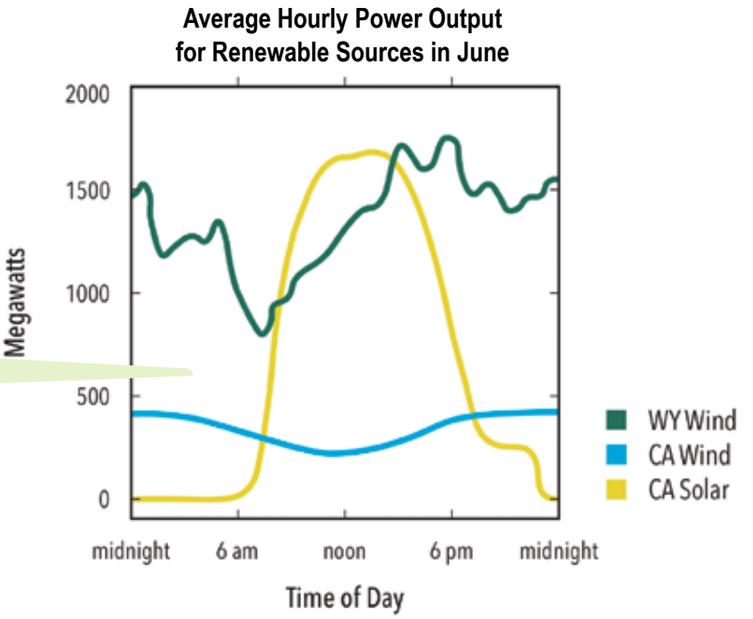
Wyoming's relentless westerly wind is a rich commodity. Wind flows east down Wyoming mountain ranges to a low spot in the Continental Divide, creating air currents that are fast enough to generate electricity but not so fast as to cause damage (usually). The National Renewable Energy Laboratory estimates that Wyoming has some of the best on-shore wind in the United States, with about 250 gigawatts worth of the high-quality resource that developers look for. That's nearly five times the total annual energy consumption of California.

Of course, not all of that wind will be captured and converted to electricity, but Jonathan Naughton, who leads the University of Wyoming's Wind Energy Research Group, thinks Wyoming could develop as much as 10–20 gigawatts of wind energy. With 1.4

gigawatts already installed, that's 7 to 15 times as much wind development as is currently in the state, and comparable to the 17.7 gigawatts produced by wind-electricity leader, Texas. But Wyoming's small and stable population isn't looking for additional electricity, and without a renewable portfolio standard (see box on page 14), the state doesn't need renewable power. If wind developers want to capitalize on Wyoming wind, they have to look for customers outside the state's borders.

Many of those would-be customers live in California. In 2015 Governor Jerry Brown signed a bill into law that upped renewable energy requirements for California from 33 percent by 2020, to 50 percent by 2030. California has already recruited a lot of solar—both rooftop installations and industrial concentrating solar collectors—to fill its renewable needs. So much so that now solar power is causing problems. On sunny days, solar power outstrips demand in the middle of the day when most people are at work, causing voltage fluctuations that can burn up lines and circuits, leading to flickering lights and even blackouts. Before that happens, California utilities pay someone, usually Arizona, to take their excess electricity, not because Arizona needs the power, but because Arizona power lines have space to handle it.

But California still needs more renewables to fill its ambitious portfolio standard. "The worst thing California could do is add more solar to their system," says Naughton. Adding in-state wind could help even out energy supply, but because sites in California are windy at more or less the same times, the benefit is minimal. So California still relies on natural gas-fired power plants to fill in when the sun isn't shining and the wind isn't blowing. California needs a reliable energy source that will produce when its solar and wind do not. What California needs is Wyoming's wind.



Wyoming's wind peaks when California's solar drops off. Data from Naughton, Wind Diversity Enhancement of Wyoming/California Wind Energy Projects (2015).

As part of a $4.5 million Department of Energy grant called *Atmosphere to the Grid: Addressing Barriers to Energy Conversion and Delivery*, Naughton has brought together engineers and economists to explore western states' energy compatibility and the impediments to their electrical union. Starting with California, he and his students compared the power production, cost, greenhouse gas emissions, and even water use under different renewable energy build-out scenarios to assess how Wyoming's wind could complement California's renewables.

Both within a day and throughout the year, Wyoming wind could fill in when California renewables lag, Naugton found. Whereas in California wind blows most in the summer and usually at night, in Wyoming wind peaks in the winter and tends to blow in the late afternoon. Combining renewables across a large geographic region can smooth their inputs to the grid, allowing greater use of renewables and less reliance on backstopping by fossil fuel power plants. Wyoming's wind could save California millions of tons of carbon dioxide emissions, billions of gallons of water that would otherwise cool traditional power plants, and $70–80 million annually.

The Front Range of Colorado could also use Wyoming's wind. Similar to California, Colorado requires 30 percent renewable energy by 2020. And like California, the more in-state wind and solar it installs, the more ramping—the big swings in power supply that cause problems for customers—it can expect, so it too could benefit from geographic diversity in its renewables. Seven other western states also have renewable portfolio standards that must be filled.

Favorable financials are also increasing the demand for wind development. A federal tax credit that incentivizes new wind projects is scheduled to expire in 2020, prompting companies to launch development before the deadline. The price of wind has also dropped markedly. Lazard's Levelized Cost approach combines capital and operating expenses into a single cost estimate to compare traditional and renewable energy sources. The 2015 Lazard study estimated the cost of generating electricity from wind is now as low as $32 per megawatt-hour, lower than the cost for coal-fired power, which starts at $65, and natural gas-generated electricity, which starts at $68. It's also much cheaper than utility-scale solar photovoltaic, which starts at $50–59. And that's *without* the federal subsidy for wind.

So now that wind energy is cheap, there's a big and growing market for renewable energy, and Wyoming's wind is some of the best in the nation, why hasn't Wyoming had a single new wind development since 2010?

LESS-STRANDED ASSETS

The first problem is transmission. "We really have no way to get any more power out of the state right now—everything's full," says Naughton. Without transmission lines, Wyoming's wind is a stranded asset, just like coal before railways. Limited transmission capacity holds back renewable energy throughout the West.

Even if more transmission lines were available to shuttle Wyoming's wind electrons, the western electricity grid is terrible at handling renewables and their big swings in power output, as California knows too well. "The new sources of electricity—solar, wind, geothermal—present a different set of transmission needs than when you built your coal plant outside the city to deliver power," says Naughton. "The bottom line from the transmission point of view is that we're trying to do things that our grid was never designed for."

Both problems—a lack of transmission and grid problems with renewables—could be alleviated by changes to the flow of electricity in the West. Collaboration among some big energy players is better connecting western energy markets and could ultimately provide greater transmission capacity to handle burgeoning renewables. The resulting more-modernized grid could overcome Wyoming's challenges to greater penetration in the western renewable energy market.

Wyoming is part of the Western Interconnection, one of three electricity grids that generate and distribute electricity in the United States. Except for a few portals along the interconnection borders, electricity is not readily shared across

POLICY BOX

WYOMING'S WIND TAX

By Lawrence J. Wolfe

Wyoming's strong, predictable, consistent winds are a world-class resource. Ranchers and farmers have harnessed the wind to pump water since Wyoming was first settled, and small-scale commercial wind projects started in the 1970s. In the mid-2000s, as wind development was escalating nationwide, Wyoming started attracting industrial-scale generation projects and new interest in building the huge transmission lines needed to march power to California and the Southwest.

As project developers blew into Wyoming, the legislature began viewing wind as a potential source of tax revenue. Wyoming does not have a corporate income tax so the only tax revenue available from existing statutes was property taxes on the towers and turbines. At the time Wyoming exempted renewable energy equipment purchases from sales tax.

In 2009, perceiving no need to incentivize wind when there was so much development pressure, the legislature cancelled the sales tax exemption except for projects already underway. Also in 2009, the legislature began evaluating additional ways to tax wind. The state embraced a generation tax, the first and only such tax on wind energy in the nation, which imposes an annual levy of $1 per megawatt hour. The legislature adopted the generation tax in 2010, and it has since brought in about $4 million per year, 60 percent of which goes to the counties where the turbines are located and 40 percent to the state general fund.

By the end of 2010, Wyoming's wind energy boom busted. No new large projects have come online in the state since. The reasons for the bust were many, including uncertainty over federal tax policy, but wind developers also perceived Wyoming as unfriendly to their industry. This perception arose from not just the generation tax, but also statewide sage grouse management policies that disrupted wind projects and other indications that Wyoming citizens and political officials were ambivalent about wind energy. Wind farms continued to be developed in states, such as New Mexico, with more favorable tax and regulatory policies.

Still, several large Wyoming wind projects are methodically moving forward, including the Chokecherry/Sierra Madre project coupled to the TransWest Express transmission line. Funded by Denver billionaire Phillip Anschutz and located south of Interstate 80 in central Carbon County, Chokecherry/Sierra Madre could become the country's largest on-shore wind energy development. As of late 2016 it was nearing the completion of federal permitting.

As such massive projects have gained momentum, the state legislature, faced with declining revenue from the collapsing fossil fuel energy industry, again sought to bring in additional money from wind. The Joint Interim Revenue Committee made two proposals: increase the generation tax from $1 per megawatt hour to $3, and make developers transfer a portion of their production tax credit (a federal incentive for wind projects) to Wyoming.

Wind developers and local governments raised a storm of protest. The issues came to a head at a September 2016 meeting in Buffalo, Wyoming, where the committee heard hours of testimony opposing the changes. Not a single person testified in favor of increasing the generation tax. Faced with that onslaught, the committee voted against both proposals. Individual legislators may bring back the generation tax increase proposal in the 2017 legislative session. However, given the strong opposition from developers and the public, and the Governor's resistance to the proposed tax, it is not likely to be successful.

***Lawrence Wolfe** is an attorney with Holland & Hart specializing in conventional and renewable energy and natural resources law.*

grids. Within each grid, electricity producers sell power to consumers, with balancing authorities, often utilities, serving as intermediaries. Although western electricity producers and consumers are connected by power lines, long-term contracts and arcane regulatory structures functionally isolate them. Those contracts and regulations constrain balancing authorities' ability to optimize real-time supply and demand. That makes the grid less efficient.

But now two of the biggest players in the western grid are partnering up. PacifiCorp is the utility that supplies power to much of Wyoming and five other western states. CAISO, the California Independent Service Operator, is the balancing authority that connects electricity buyers with utilities for 80 percent of California and a bit of Nevada. In 2014, the two groups agreed to sell power back and forth, and the paradoxically named Regional Energy Imbalance Market was born. Utilities in other states have since joined the market and the footprint of the regional market is now substantial.

Grid integration is a game changer for Wyoming. First, it could provide the transmission Wyoming needs to connect to renewable energy consumers. CAISO and PacifiCorp commissioned a study on the benefits of regional coordination, which showed that grid integration would lead to more efficient use of existing transmission lines, but also greater capacity to build new lines. The study concludes that when better integrated utilities plan for energy transmission together, costly DC lines, like those needed to move electricity from Wyoming to distant California markets, will become more feasible (although still slow given the onerous regulatory hurdles of siting lines).

Second, grid integration creates a bigger market, connecting energy producers and consumers across a much larger service area. That keeps power flowing logically from areas of high production to areas of high demand, alleviating the power surges and troughs that currently plague the grid. It also realizes cost savings. Cindy Crane, who oversees PacifiCorp's operations in Wyoming, Idaho, and Utah says the Regional Energy Imbalance Market makes it easier for the utility to buy someone else's excess energy instead of always generating their own. "And that helps us keep our rates low."

The emerging western energy market has enjoyed some early successes such as lower rates, but full grid integration is still in the works. Still needed is agreement among the participants on equitable distribution of costs, including new regional transmission fees, grid management charges, new meters, and others. Wyoming has some of the cheapest electricity anywhere, so while the integration efficiencies may be a net gain for the six-state PacifiCorp market, Crane worries that Wyoming's rates could increase. "This isn't an opportunity for the California utilities to get a windfall," Crane says.

There's also the issue of governance. CAISO is currently managing the emerging market and its utility participants. But some western states won't stomach having their utilities governed by a California-based balancing authority forever. Wyoming players in particular, would like to see an independent governance structure that would loosen California's control.

Grid integration makes California cautious too. Policy-makers prefer to keep new renewable energy jobs in-state, rather than exporting them to Wyoming. And some West Coast environmental groups worry about pulling power from a grid sullied with carbon-fired electrons. Kathryn Philips, Director of Sierra Club California, expressed this fear: "A regional power market could increase greenhouse gas emissions and prop up out-of-state coal plants that threaten clean air and water across the region."

The chasm between Wyoming and California is filled with ideological differences. In the end, will western states tie the knot through a fully integrated grid? "I think eventually they will work it out," says Rob Godby, a University of Wyoming economist on the Department of Energy grant. "The benefits are too big on both sides to walk away from it."

Integrated energy markets could shift the future of renewable energy in Wyoming. But the grid is just one of two significant roadblocks to new wind development in Wyoming. The other is desire.

ROLLING UP THE WELCOME MAT

Even if transmission is solved through more lines and better grid integration, wind energy is anathema to many Wyomingites, including key policymakers. Ironically, it's the environmental downsides of climate-friendly wind energy that give Wyomingites pause.

Why does a state that typically embraces big energy balk at the prospect of more wind turbines? Well-known impacts to birds, bats, and other wildlife worry some, but viewshed concerns dominate. Towering wind turbines could chop up Wyoming's prized horizons.

A 2011 study by Arizona State professor Martin Pasqualetti found that similar perceptions motivated opposition to four wind farms around the world, regardless of location. Immutability, the sense that "the landscapes with which we are most familiar, those that provide both our livelihoods and our greatest comfort will not change over time," creates strong resistance to towering wind turbines, Pasqualetti wrote.

The power of wind farms to permanently change the landscape that Wyomingites love, is something that Wyoming Senator Cale Case struggles with: "My son, my grandchildren will never see the Wyoming I saw," Case told the *Casper Star-Tribune* in May. "With wind, that viewshed is lost forever. It is severed." (Wind farms can be decommissioned, but it hasn't happened much yet in this

relatively new industry.)

Professor Pasqualetti also found that opposition to wind stems from a sense of imposition, the feeling that wind projects are "someone else's idea, for someone else's benefit."

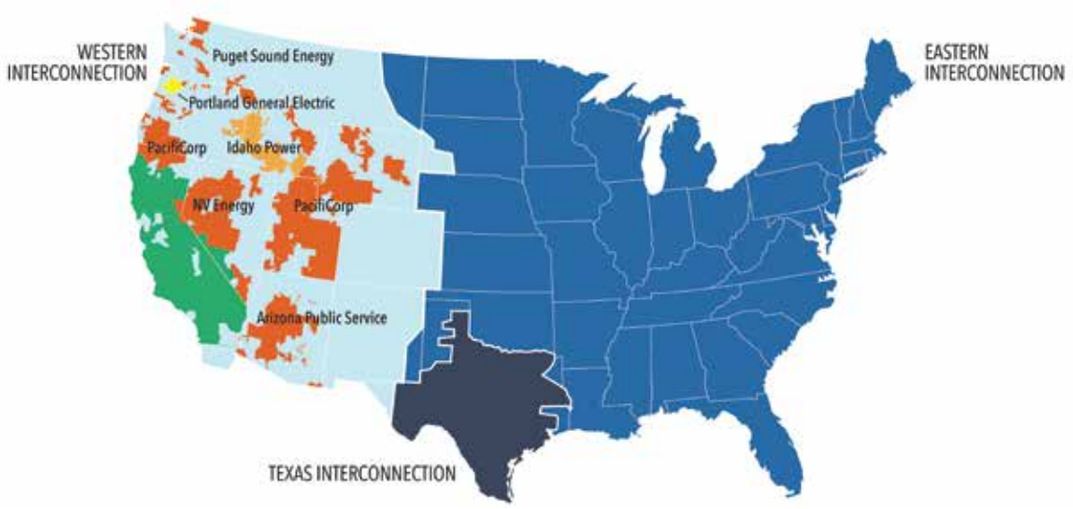
Wyoming Senator Ogden Driskill echoed the sentiment that Wyomingites don't have much to gain from wind. "If wind doesn't provide some form of significant benefit to the state of Wyoming, I don't care if it is here," Driskill told the *Wyoming Business Report*.

Whereas fossil fuel companies pay severance taxes to the state for removal of non-renewable resources, severance taxes don't apply to wind, even if it feels like the viewshed is lost forever. The sense that wind farms create a permanent loss has helped to motivate Wyoming's unique $1 per megawatt-hour wind production tax (see box, page 17).

In 2016, the Wyoming legislature's Interim Revenue Committee, on which Driskill and Case both serve, considered increasing the wind production tax to better compensate Wyomingites for viewshed losses. And it wouldn't hurt if it could also raise more revenue for the state's ailing economy (if the higher tax doesn't kill interest in new wind developments outright). The proposal to up the wind tax failed that time but could come back.

As Pasqualetti found, lots of communities oppose wind development. But wind has a particular perception problem in coal country. As coalmines lay off workers and wind turbines sprout up in the United States, some on the Interim Revenue Committee perceive that pro-wind factions are "seeking to shut down the coal industry," the *Casper Star-Tribune* reported in May.

The idea that Wyoming's wind development is driving coal out of business "flat out isn't true," Naughton contests. Because with regulations and social pressures for energy sources with low carbon dioxide emissions, "if it wasn't wind it would be something else." Given its low price, that something else is currently natural gas, another Wyoming commodity.



Three grids, known as interconnections, cover the continental United States. Within the Western Interconnection, utilities are gradually joining the Regional Energy Imbalance Market under the California Independent Service Operator, making energy exchanges more efficient. Data from CAISO.

Economist Rob Godby, takes it a step further. He says that instead of being competitors, wind and coal are good partners, working well together to capitalize on multiple markets. Wyoming sells wind energy as electrons to Western Interconnection markets, while the state exports coal in raw form by railcar across grid boundaries to the Eastern Interconnection and Texas.

But the wind-coal tension persists, perhaps because of the perception that the ideas that have spurred wind energy development—including the need for clean energy that will slow climate change—are the same ideas that have hampered the coal industry. Thus to embrace wind is to be complicit in the demise of coal.

Regardless of the reason, the dominant narrative is that Wyoming, like an energy colony, would bear the costs of big wind development—loss of viewsheds and traditional economies—without reaping the benefits. But that assumes that without severance tax and mineral royalties, wind has little to offer the Wyoming economy. The data tell a different story.

THE SURPRISING FINANCIAL BENEFIT OF WIND

It turns out that Wyoming stands to make real money from wind, even without an increase in the wind tax. In a 2016 report to the Wyoming Business Council and the Carbon County Economic Development Corporation, Department of Energy grant participants and UW economists Godby, Tex Taylor, and Roger Coupal estimated the potential revenue from five Wyoming wind projects in the works. Those include what would be the biggest wind development in the United States, the three-gigawatt Chokecherry-Sierra Madre wind farm near Rawlins, plus four more projects scattered around the state. Together, they would produce 6.1 gigawatts of wind power.

Godby and his colleagues found that, if completed, those five projects would generate an estimated $1.9–2.1 billion in tax revenue in Wyoming over 20 years from property taxes, sales and use taxes from construction and operating activities, and the current wind production tax. Wind development also creates some jobs, although mostly in the construction phase, and most of that comprising a specialized, temporary workforce. Still, new jobs, including some permanent ones, with an average annual salary of about $58,000 would generate $3 billion in estimated labor income to Wyoming over 20 years. Altogether, those five wind farms would yield some $7.1 billion in new economic activity to the state. Big numbers to be sure, but are they enough to matter?

When I ask him over coffee whether an even bigger build-out of wind, on the scale estimated by Naughton, could generate enough revenue to fill the hole in Wyoming's economy left by fossil fuels, Godby at first says, "It's not even close." But then he pauses and says, "Let's just do a thought experiment."

We assume 12 gigawatts of new wind, which would include the six gigawatts of wind farms on the drawing board plus as many new projects not yet conceived. That's at the lower end of Naughton's estimate of 10–20 gigawatts of realistically producible wind power. (Godby, however, thinks it's on the outer limits of what's possible.) He doubles the tax revenue projections from the five new wind projects to represent the hypothetical 12 gigawatts of new wind. That would yield an average of $210 million per year, without considering jobs and other forms of economic stimulus from wind development.

For context, declines in severance taxes from oil, gas, and coal during 2015 totaled $340 million in lost tax revenue to Wyoming. So potential new tax revenue from wind would equal more than 60 percent of lost severance taxes (recognizing that severance taxes are not the only revenue source from fossil fuels). Put another way, total new tax revenue from 12 gigawatts of wind would be slightly greater than the state's current budget deficit, which the Wyoming Legislative Service Office estimates at $203 million per year after major reductions in spending.

As important as wind revenue could be, it does not neatly offset losses from fossil fuels. First, tax revenue from wind is "lumpy," says Godby. More revenue would come early on during the construction phase, so some years would see well above $210 million in tax revenue and other years would see less. A larger proportion of wind's tax revenue—40 percent—would go to local governments compared with just 9 percent from coal for instance. That would boost revenue in places that have not traditionally benefitted from mining, but leave gaps at the state level and in counties reliant on coal. Wind tax revenue would also contribute significantly to state coffers including the School Foundation account that funds K-12 education, but would not completely fill the losses from fossil fuels. The other caveat, Godby says, is that it will take at least 10 years to see new money from wind given the slow pace of creating wind and transmission projects, while the budget crisis is now. Still, wind development could be a big chunk of the long-term economic diversification puzzle.

Naughton adds that wind development can also be an "enabler," kicking open the door to other revenue sources for Wyoming. "What kind of economic opportunities can we have here because we have cheap renewable electricity—the cheapest in the country?" he asks. Big data companies like Facebook, Amazon, and Google are on track to be among the biggest power users in the world, already using an estimated 10 percent of global energy production, according to one industry report, *The Cloud Begins with Coal*. They're looking for clean energy sources.

Case in point, in late 2016 Microsoft committed to purchasing 237 megawatts of wind from Wyoming and Kansas for its Cheyenne data center. Since, "we've probably missed the ability to attract lots of wind turbine manufacturers because other states did that," says Naughton, enabling data centers and other electricity-hungry industries is a key opportunity.

From ranchers who lease land for turbines, to counties that get a big share of wind farm tax income, many individuals and communities would gain financially from more wind development. The question is whether those gains are enough to overlook the costs, to see past the turbines on the horizon. If the answer is yes, Wyoming will have to move fast.

STANDING AT THE THRESHOLD

Even with its first-class wind resource and proximity to hungry western markets, the window of opportunity for Wyoming to play big in the wind market is closing. Technological advances in wind turbines, "have improved productivity in places that have less wind resource than we do," letting neighboring state generate comparable power to wind-rich Wyoming, says Godby. Wyoming's competitiveness is fading.

Plus, the rush for new wind developments that is sweeping through the United States won't last forever. Wind turbines are being added at twice the rate that will be needed in the 2020s, says Godby. "What that suggests is that the big boom to build wind turbines might slow down significantly" in the next decade. If the pace of current transmission projects is any indicator, new transmission lines take 10 years or more to site, permit, and build. That means Wyoming will have to get those projects off the ground quickly to capitalize on the wind market before it fades. Godby thinks it's not too late.

If indeed, Wyoming chooses to develop wind at levels meaningful for economic diversification, what would that look like? Assuming 6–12 gigawatts of total wind development from two-megawatt turbines, Wyoming could see between 3,000 and 6,000 turbines. Naughton says southern Albany County and Laramie County north of Cheyenne, ideal because they don't conflict with sage-grouse populations, could see the most development. Wind farms could also sprout up north of there, near Douglas and Casper.

"Would you see more wind? Yes." Is the whole state going to look like Tehachapi, California, with its endless forest of wind turbines? "No," says Naughton. But some remote places would be profoundly changed, challenging the desire for "immutability" of our western landscape.

The good news is that the future of Wyoming's wind is a choice, not an arranged marriage. It's less a question of whether clean-energy-hungry western states will drive unwanted wind developments to Wyoming. The question now is whether Wyoming might want to court that new market.

Naughton thinks that choosing wind will be one step of many needed to finally end Wyoming's boom-bust problems. "If we get it right, we're going to say, wow, we did it right. If we get it wrong, you could really have to repeat this whole thing again."

Nicole Korfanta *is the associate editor of* Western Confluence *and director of the William D. Ruckelshaus Institute of Environment and Natural Resources.*

FURTHER READING

Energy and Environmental Economics, Regional Coordination in the West: Benefits of PacifiCorp and California ISO Integration (San Francisco, Energy and Environmental Economics, 2013).

Robert Godby, David T. Taylor, and Roger Coupal, *An Assessment of Wyoming's Competitiveness to Attract New Wind Development, and the Potential Impacts Such Development May Bring the State* (Laramie: University of Wyoming, 2016).

Lazard, *Lazard's Levelized Cost of Energy Analysis—Version 9.0* (New York: Lazard, 2015).

Jonathan Naughton, *Wind Diversity Enhancement of Wyoming/California Wind Energy Projects* (Laramie: University of Wyoming, 2015).

Jonathan Naughton, Thomas Parish, and Jerad Baker, *Wind Diversity Enhancement of Wyoming/Colorado Wind Energy Projects* (Laramie: University of Wyoming, 2013).

Martin J. Pasqualetti, "Opposing Wind Energy Landscapes: A Search for Common Cause," *Annals of the Association of American Geographers* 101 (2011).

Find links to these documents at westernconfluence.org.

Net-Zero Energy Homes in Wyoming

THE NEXT FRONTIER?

Courtesy Jon Gardzelewski

By Kit Freedman

On an unseasonably warm day last October, Richard Fox pulled up to the construction site of his future home near Pavillion, Wyoming, in an old Toyota pickup. Builders were fast at work raising walls and securing exterior panels in hopes of getting a roof in place before the snow started to fly. Located a few miles from where he and his wife, Hadley, spend their winters overseeing a small farming operation in west-central Wyoming, the site overlooks an irrigated field of pinto beans and alfalfa giving way to expansive views of the towering Wind River Mountains in the distance.

So far, the home looked like any other. Set upon a large foundation amid stacks of milled lumber, piles of dirt, and heavy equipment, an airy labyrinth of posts and studs soared to the sky framing windows and interior walls.

But what's different about the Fox place is that, when it's all said and done, the home won't generate a utility bill.

That's because it was engineered to produce as much energy as it consumes on an annual basis. It's what's known as a net-zero energy home. And if all goes as planned, it will be one of many in Wyoming.

"We're confident that if we can build a couple of these homes, more people will see them and will want one," says Jon Gardzelewski, the architect who designed the home, as he leads me on a tour around the build site. An associate lecturer of architectural engineering at the University of Wyoming, Gardzelewski specializes in ways to make buildings use less energy. "Ten years ago," he tells me, "someone interested in sustainability might tack on a few solar panels or shading devices to help increase building performance and make their home more sustainable. While that can do some good," he admits, "in most cases, poor design made them inefficient for passive solar heating and solar control."

So in 2013, he and colleagues at the University of Wyoming set out to change that by forming the Building Energy Research Group, or BERG. Gardzelewski teamed up with Tony Denzer, head of the Civil and Architectural Engineering Department at UW, Liping Wang and Gang Tan, assistant professors in the College of Engineering with expertise in heating and cooling systems, and Ben Gilbert, an economist in the Department of Economics and Finance. The group conducts research on topics such as building performance and renewable energy options for residential customers like solar photovoltaics, wind, and geothermal, with the overarching goal of helping to improve the energy performance of buildings in Wyoming.

While it may sound far-fetched, the net-zero energy building concept is actually quite simple: start by reducing a home's heating, cooling, and lighting loads as much as possible through architectural design and detailing (think Energy Star appliances and LED light bulbs); then make up the remaining energy needs with on-site wind or solar energy production. Homes are typically grid-tied for backup and to unload excess energy back onto the grid.

"What's fundamental to net-zero energy designs is thick, well-insulated walls with super tight construction," explains Denzer. "Then orientation."

In the case of the Fox home, this equates to super-insulated exterior wall panels, air-tight spray foam insulation between the studs, and an abundance of south-facing windows to take full advantage of the sun's natural energy. By incorporating lots of glass on the south side of the house and very little on the other three sides, the home is essentially engineered to heat itself through passive solar design.

Here's how it works: in winter, low-lying sun shines directly through south-facing windows and warms up a large concrete floor. The thermal energy absorbed during the day then radiates into the living space at night,

keeping the home at a comfortable temperature well after the sun goes down. A radiant heating system, powered by solar panels on the roof, runs through the floor and distributes heat evenly through the home. Heavy window shades help keep heat in at night.

"There's enough thermal mass in this floor to keep this home at a pleasant, warm, livable temperature even on the coldest winter nights," assures Gardzelewski.

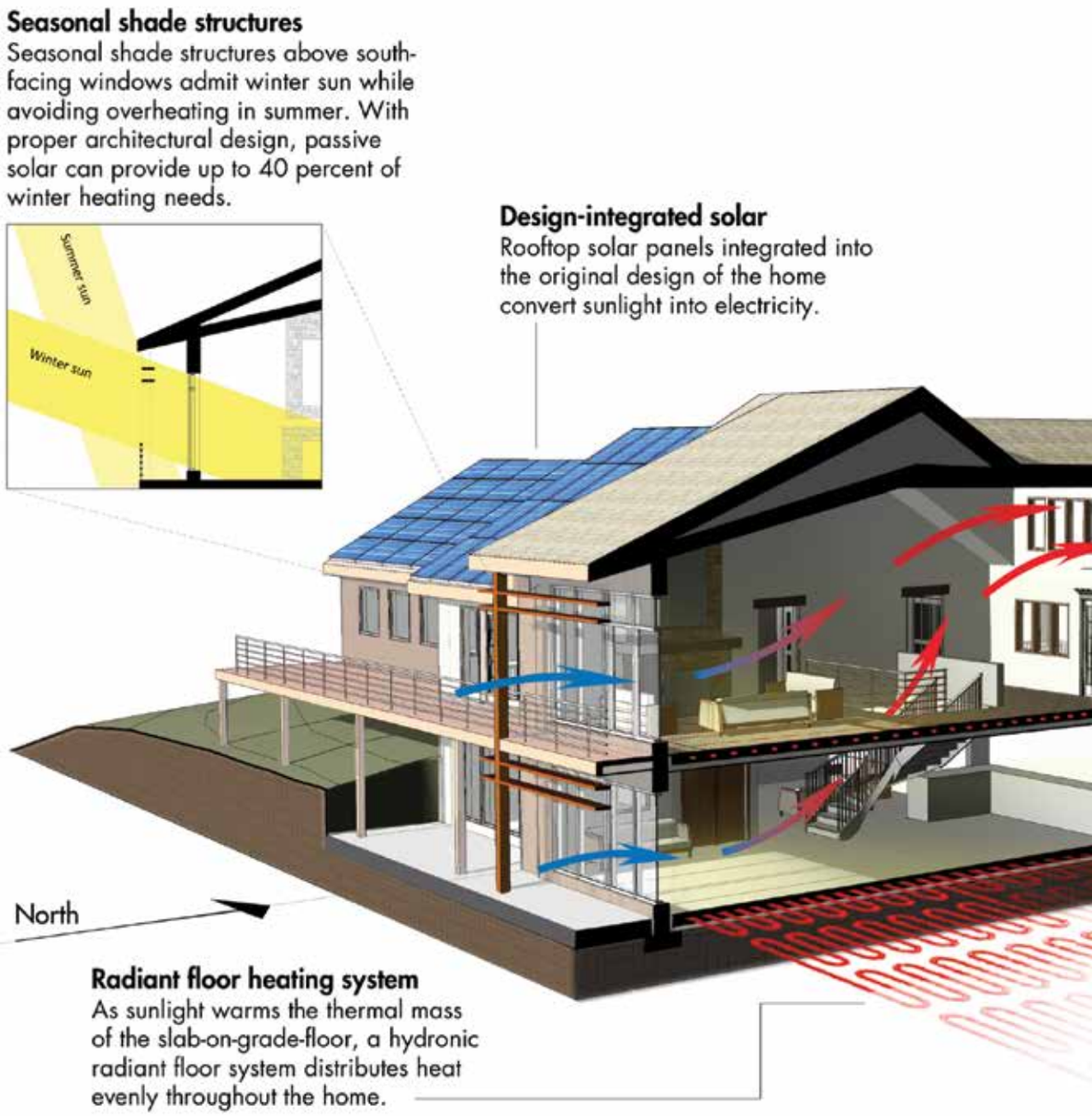
Alternately in summer, rooftop overhangs block summer sun to prevent overheating. Strategically placed windows move air across the thermal mass of the floor, drawing out stored heat to cool the building.

"Every important technical challenge with regard to green building has already been solved," asserts Denzer. "There is no new futuristic discovery that we're waiting on. You can build a net-zero house tomorrow with commercially available, off-the-shelf stuff."

To prove the point, BERG worked with architectural engineering students at the university to develop a catalog of net-zero energy home designs available for free to Wyoming citizens and homebuilders, a product line they've termed *Frontier Zero*.

"We looked at the housing market in Wyoming and other states across the West to see what kind of homes people were buying," says Gardzelewski. As a result, many of the designs in the catalog were inspired by the craftsman style and other western traditions that complement the landscape and history of architecture in Wyoming. Model names like "Red Desert," "Elk Mountain," and "Fremont Peak," are designed to appeal to Wyoming residents.

"We have big houses, we have small houses, we have homes that were designed for narrow lots, designs that are urban, suburban, and rural," explains Denzer. Interested clients who don't find exactly what they want in the catalog can contact BERG to come up with a custom design. Though the building requirements seem prescriptive, Denzer says there's flexibility when designing and building net-zero energy homes to accommodate finances, client preference, or whatever the builder is comfortable doing.



With the first edition of the *Frontier Zero* catalog out and another on the way, BERG hopes to soon build Wyoming's first neighborhood of net-zero energy homes and establish a net-zero energy home market in Wyoming.

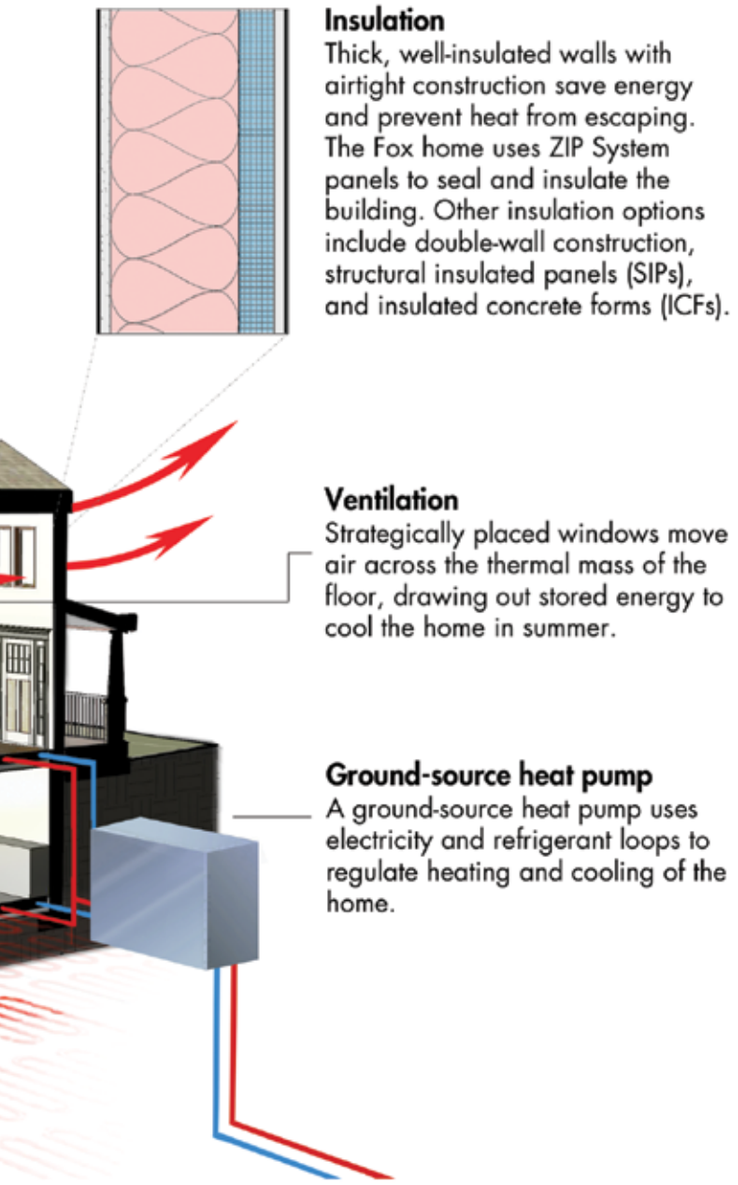
Elsewhere around the country, net-zero energy homes have become increasingly popular in recent years, propped up in part by policies and initiatives that encourage, even mandate, zero-energy building designs.

For example, in California, which claims nearly half of the more than 3,500 residential net-zero energy buildings in North America, state leaders in 2007 set an ambitious goal requiring that all new residential construction be net-zero energy by 2020 and that all new commercial construction in the state be net-zero energy by 2030. And just south of Wyoming's border in neighboring Colorado, communities like Fort Collins and Boulder have set aggressive targets toward emissions reductions that use net-zero energy techniques and building styles as a means of achieving those goals.

Still, the net-zero movement has been slow to catch on in the state. "The barriers at this point are cultural, and maybe a little bit economic in the sense that it costs a little more upfront," asserts Denzer.

About 10 percent more, to be exact.

To demonstrate, he lays out a scenario: say you build an ordinary home and the monthly mortgage payment is about $2,000. You'd still have to pay for heat and electricity, which is probably around $200 a



Insulation
Thick, well-insulated walls with airtight construction save energy and prevent heat from escaping. The Fox home uses ZIP System panels to seal and insulate the building. Other insulation options include double-wall construction, structural insulated panels (SIPs), and insulated concrete forms (ICFs).

Ventilation
Strategically placed windows move air across the thermal mass of the floor, drawing out stored energy to cool the home in summer.

Ground-source heat pump
A ground-source heat pump uses electricity and refrigerant loops to regulate heating and cooling of the home.

month. So, it's $2,200 for the ordinary house including utilities, but it's also $2,200 for the net-zero house. If you build a net-zero energy home, the mortgage payment will be slightly higher, around $2,200 a month, but there is effectively no utility bill.

"You're paying a 10 percent premium up front, but you're getting back enormous benefit by not paying a utility bill for the life of the home," explains Denzer. Not only that, net-zero homes aren't subject to fluctuating utility prices and may actually prove to be a moneymaker in the long run.

"You can build a net-zero house tomorrow with commercially available, off-the-shelf stuff."

– Tony Denzer, Department Head, Civil and Architectural Engineering

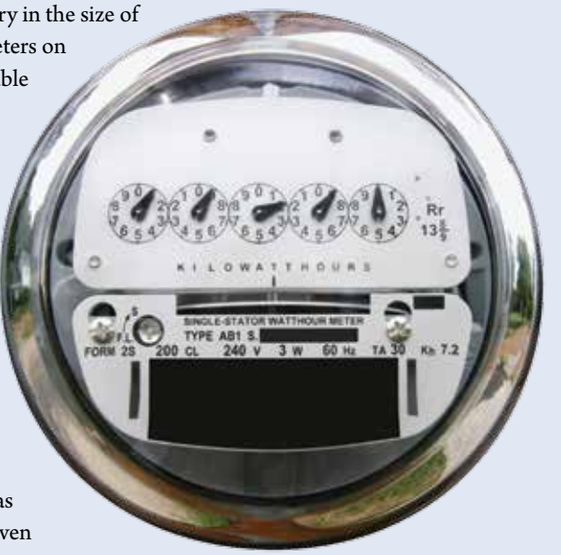
POLICY BOX

NET METERING

By Stephanie Kessler

Net metering lets customers tie small-scale renewable energy systems such as solar panels into the grid to offset their energy bills. With net metering, the electricity meter runs forward when the customer takes energy from the grid (such as at night when the solar panels aren't generating) and it runs backwards when the home is feeding surplus energy into the grid (such as when the sun is shining and no one is home using appliances). At the end of the month, the utility charges the customer only for the net energy use. A customer who produces more energy than he uses earns kilowatt-hour credit that is applied to the next month's electricity bill.

Forty-four states have laws or rules governing net metering. States vary in the size of systems, number of meters on a property, and renewable energy technologies they allow; how customers are billed; how credits roll forward; and other parameters. In Wyoming, at the end of the calendar year, the utility pays the customer for any remaining energy credits at a wholesale rate. Wyoming's law was created in 2001, and given that renewable energy systems have advanced over the last 15 years, is due for an update. For example, Wyoming only allows net-metered renewable energy systems up to 25 kilowatts. That's more than enough for the average residential home, but too small to be worth the investment for larger buildings and facilities such as commercial businesses, government offices, and educational institutions.



Solar is booming across the country as customers clamor for low-carbon energy and cost savings. The solar energy sector now supports 218,000 jobs nationwide. Many states are inviting this economic surge by making their net metering laws more flexible to accommodate a wider range of renewable energy options such as wind and hydropower. A recent proposal to update Wyoming's net metering law would have increased system size limit to 1 megawatt for non-residential facilities, allowed for multiple meters on a single utility bill, and adjusted the billing time period to April 1 to March 31 so that customers could use up credits they earn during the sunny summer over the darker winter months. Such changes could make new solar installations—and the jobs and energy savings that come with them—feasible in the state. However, utilities protested and the proposal failed in legislative committee.

***Stephanie Kessler** is director of external relations for the Wyoming Outdoor Council.*

While net-zero energy homes can be built for just a little more than the cost of a conventional build, Gardzelewski says they sell for a lot more once constructed.

"What we've seen around the country is that people are willing to pay a relatively high premium for homes with design-integrated solar and no utility bill," says Gardzelewski.

Unfortunately, increased value for net-zero energy homes is something appraisers in Wyoming have yet to acknowledge. So even getting a bank loan for the extra 10 percent to build a net-zero home can be a challenge.

"We might try to work on that someday," says Denzer.

Back in Pavillion, Gardzelewski continues to show me around the build site, pointing out nifty features like the ground-source heat pump that drives the radiant heating system in the Fox home.

"There's an old adage that goes something like, 'pioneers get slaughtered while settlers prosper,'" explains Gardzelewski. "But we're trying to help the pioneers, the early-adopters, prosper too."

When I ask Richard Fox if he's at all worried about being the first to build a BERG-designed home, he says not really. While he had some concerns that building a net-zero home would mean sacrificing priorities like spaciousness and livability, the BERG design actually enhanced those things. He says the net-zero choice made sense financially and environmentally.

"We live in a beautiful and unspoiled part of the state. As farmers, we pride ourselves on being good stewards of the land and environment."

Kit Freedman *is the Project and Outreach Coordinator for the Ruckelshaus Institute of Environment and Natural Resources at the University of Wyoming. Learn more about BERG's research and design services at uwberg.com.*

POLICY BOX

COMMUNITY SOLAR

By Stephanie Kessler and Scott Kane

Community solar—sometimes referred to as a solar garden or virtual net metering—is when several households, businesses, or other entities invest together in a solar installation and share the electricity it produces. A typical community solar project ranges from about 200 kilowatts to 2 megawatts (equivalent to 2,000 kilowatts). That's about a half-acre up to a couple of acres of solar panels. Most such projects are located within or near the communities they serve. Each member buys a "share" of the energy generated. The local utility monitors how much electricity the community solar installation feeds into the grid each month, and subtracts that amount from the members' utility bills according to the size of their shares. For example, if an installation produces 60 megawatt-hours one month, and has 100 members with equally sized shares, each of their electricity bills for the month will be discounted by 600 kilowatt-hours.

Community solar benefits consumers in many ways. It allows customers who do not own property, who have shaded roofs, or who cannot afford a major home installation to invest in solar energy. It gives customers ownership over their electricity generation. And these mid-sized projects tend to cost less per energy unit than smaller individual solar installations.

Twenty-five states have active community solar projects. In some states, like Colorado, legislation has paved the way for community solar by putting into law how utilities must meter and account for such projects. In states that don't have existing installations or state laws, such as Wyoming, communities might negotiate directly with their utilities or approach state utility regulators to create a community solar project. For example, the Town of Jackson and its utility, Lower Valley Energy, are investigating a possible community solar installation.

Stephanie Kessler *is director of external relations for the Wyoming Outdoor Council.* ***Scott Kane*** *is co-founder and co-owner of Creative Energies, a solar installation company based in Lander, Wyoming.*

Courtesy Scott Kane/Creative Energies

The Michael B. Enzi STEM building is one of several new buildings on the UW campus.

DOING MORE WITH LESS

How energy efficiency and conservation can decrease UW's utility bills

By Rachael Budowle

Keeping the lights and heat on at the University of Wyoming is a challenge. A campus quickly expanding with energy-intensive buildings is straining UW's ability to meet its energy demand, even with a $10.8 million annual utility budget. While Wyoming enjoys some of the lowest energy costs in the country, the university is searching for ways to save money amidst major state budget cuts. UW Operations, the division responsible for buildings and utilities on campus, has so far managed energy demand with straightforward efficiency measures in both new and existing buildings. But with many energy-saving efforts already accomplished and even more new buildings in the queue, UW is now looking for additional ways to save both energy and money as the campus grows.

University campuses typically reduce energy use and utility bills through both conservation and efficiency efforts. Conservation relies on cost-effective behavioral changes, as simple as turning off the lights, to use less energy. UW has instead mainly focused on efficiency measures—infrastructural and equipment upgrades that perform the same work with less energy. Those measures have stabilized energy demand even as the campus has grown to over seven million square feet, an increase of nearly one million square feet in the last ten years. Those efficiency measures have included lighting retrofits and ventilation upgrades in multiple buildings. Building automation systems, which control indoor climate and lighting based on typical occupancy schedules, have also yielded substantial savings.

The existing Biological Sciences building originally constructed in 1969, for example, underwent many of these lighting, ventilation, and building automation efficiency upgrades in 2012 and 2013. Improvements include equipment that recovers and recirculates heat from air handling units in the winter; low-flow fume hoods, which ventilate chemicals at workstations; low-horsepower laboratory air supply and exhaust valves; energy-efficient fluorescent lighting; and 50 percent reduced air exchange rates when labs are unoccupied, which decreases the total energy needed to move air in and out of the building. The building's energy use per square foot now rivals that of some office buildings on campus, a major achievement for a historically high-energy-use laboratory building.

Many efficiency efforts in existing buildings have additional benefits beyond energy savings. A major air filter upgrade implemented across 17 buildings in 2014 has reduced maintenance and waste costs, as the new filters need less frequent replacement than older models. UW Operations estimates that the filter upgrade in the Berry Biodiversity Center alone will result in a 37 percent cost reduction compared to older filters due to savings in energy, labor, and waste.

UW has managed energy use in some of its new buildings as well. The Bim Kendall House, a 1950s-era building renovated into offices and meeting rooms for the Haub School of

Environment and Natural Resources, relies on simple energy-saving measures. Opening a window cools a room and daylight reduces reliance on light fixtures. Variable frequency motors, expensive on the front-end, pay back quickly by reducing the amount of energy needed to push hot water through the baseboard heating system. Roof-mounted photovoltaic panels further offset the already relatively low energy use in this building. The even newer Marion H. Rochelle Gateway Center uses LED lighting throughout and operates with highly efficient chillers and boilers, which, in combination with its building automation system, result in a well-performing building.

While these efforts have reduced energy use in existing and new UW buildings, additional buildings will increase overall demand for heating, cooling, and electricity. Recent and upcoming buildings are among some of the most energy hungry on campus. The Michael B. Enzi STEM Building completed in spring 2016, the soon-to-be-completed High Bay Research Facility, and the in-design Engineering Education and Research Building and the Center for Integrative Biological Research, all require energy-intensive laboratory infrastructure that will add to UW's utility bill even as the university's budget decreases. "We've got a lot more to do," to save energy and reduce utility costs, says Forest "Frosty" Selmer, deputy director for utilities management, who has been a champion for many of UW's existing efficiency efforts. "A lot more."

UW stakeholders, including the Campus Sustainability Committee, students, and UW Operations itself, are now advocating for next-level energy reduction measures in both existing and upcoming buildings. Selmer suggests installing digital thermostat controls in older buildings that lack automation systems to help regulate indoor climate and save energy. He also recommends frequent retro-commissioning, a sort of building tune-up that examines

The Bim Kendall House at the University of Wyoming is home to the Haub School of Environment and Natural Resources.

building performance to inform upgrades to building systems and major equipment—most commonly those related to air handling and distribution, heating, and cooling.

Another solution would be to fully fund UW's Conservation and Efficiency Revolving Fund (CERF), which received approval from the university administration in 2014. The CERF would accept competitive proposals for investment in high-payback energy reduction projects and then track and revolve financial savings back into the fund to support future projects. The university piloted the CERF with funding from UW Operation's major maintenance budget to support projects such as a proposal from undergraduate students to upgrade metal halide lighting to more efficient LED's on Prexy's Pasture. But the CERF requires a major infusion of external funding to invest in bold energy-saving projects. Similar revolving funds have been extremely effective at universities and colleges across the country, with projects yielding an average 28 percent return on investment. The CERF could serve as both a money-saver and a money-maker for efficiency at UW.

Designing all new buildings to use less energy from the outset would further curb energy use at UW. Students in the Haub School of Environment and Natural Resources spring 2016 Campus Sustainability course proposed minimum building efficiency standards for UW. Those standards, now in consideration for inclusion in the internal UW Design Guidelines, focus on energy efficiency and building life cycle analyses to account for operating costs as well as construction costs. And room remains to adopt even bolder standards.

Conservation—the behavioral change counterpart to efficiency—could also be an important part of the solution, one that Bill Mai, Vice President for Administration who oversees UW Operations, appreciates. "I think it really starts with people using what they need to use," says Mai.

Students in the Campus Sustainability course have led the way on one major conservation effort by researching fume hoods, many of which operate on a variable rate system—the more open the sash (or window), the more energy the fume hood uses. They examined campaigns at universities across the country that ask lab users to keep fume hood sashes shut when not in use and as low as safely possible while in use. At MIT, "Shut the Sash" saves $41,000 per year for the Chemistry Department alone. The UW students designed a similar program that launched in January 2017 with the support of Risk Management and the Campus Sustainability Committee. The program is just one example of a simple behavioral change. A concerted, campus-wide conservation program could realize substantial cost savings for the university.

UW still has plenty of room to implement combined conservation and efficiency measures to further reduce energy consumption and cut costs. Oklahoma State University, an institution in a state with an energy economy similar to Wyoming's, has saved over $30 million through energy efficiency and conservation since 2007. Major savings are possible when a university invests in energy reduction as another resource, alongside traditional and renewable energy. But such upfront investment and long-term thinking about savings can be difficult even in the best of times, especially in energy-rich Wyoming.

While these investments remain challenging in Wyoming with its abundant and low-cost energy, UW compares to institutions like sustainability leader Colorado State University in terms of energy use per square foot of building space. But in terms of square foot—and thus energy use—per student, UW is among the least efficient universities in the country. "We've got some poorly utilized buildings," says Selmer. Since it's far easier to raise funds for new building projects than it is for renovations of existing space, the campus is likely to continue to expand for the foreseeable future.

With more new buildings on the horizon, the university's high energy use per person and overall utility costs will only increase. In light of that, Mai says it's time to think big about efficiency. "If you don't do it now, we are handing a massive problem forward to whoever succeeds us. And it just seems really irresponsible to do that."

***Rachael Budowle**, a PhD candidate in Anthropology, co-chairs the UW Campus Sustainability Committee and teaches sustainability courses in the Haub School.*

DOWNSIZED

Saving Energy by Living Small

By Kristen Pope

Before Macy Miller moved into her 232-square-foot tiny home in Boise, Idaho, she lived in 2,500 square feet in neighboring Meridian, Idaho, and typically spent "a couple hundred a month" on utilities, including gas and electricity, with some months costing even more. "It was never fun to pay a $400 electric bill," she says.

After moving into the tiny home, her family's typical monthly electricity bill dropped to just $8-12; the highest was $50. She shares her home with her partner, James, their two small children, Miles and Hazel, and a 140-pound Great Dane named Denver.

Miller is one of many people who are embracing tiny home living in an effort to downsize and simplify their lives. One benefit of downsizing comes in the form of reduced energy consumption. While society waits for changes in technology, infrastructure, and policy to address our carbon emission woes, the most straightforward piece of the solution may take a cue from the tiny house movement—get smaller, and emit less carbon in the process.

Fifty years ago, the average American single family home was 1,500 square feet. In 2015, newly constructed homes averaged nearly 2,500 square feet. Americans consume more and more energy to heat and cool these growing homes and power the devices inside, from laptops to microwaves. Per capita energy consumption jumped more than a quarter, from 250 million BTUs in 1960, to 316 million BTUs in 2010 according to the US Energy Information Administration. (A BTU, or British Thermal Unit, is the amount of energy needed to heat 16 ounces of water one degree Fahrenheit.)

Courtesy Murphy Robinson

Murphy Robinson lives in a 72-square-foot tiny home in Vermont.

While tiny house dwellers typically use less energy overall than those who live in traditional homes, official research on the topic is lacking. Many owners put their homes on trailers and classify them as recreational vehicles both for portability and to avoid mandatory minimum structure sizes required by building codes.

Despite the lack of hard data about energy use in tiny houses, many experts believe they represent a move in the right direction in terms of energy consumption. Kateri Callahan, president of the Alliance to Save Energy, a nonprofit coalition seeking enhanced energy efficiency, points out that tiny homes—typically only 100-450 square feet—are just a fraction of the size of the typical US home.

"That is downsizing significantly," Callahan says. "Where you're going to get the largest reduction is energy use because you're not heating and cooling so much space."

That was certainly true for Miller and her family in Boise. "In a tiny house you're more aware of what you're doing in every way," says Miller. She can name every energy-consuming item in her tiny home including the propane-powered water heater, stove, heater, and a handful of electrical devices, including an air conditioner. These systems keep the family cozy on 14-degree-below-zero days—aided by ample body heat—and maintain a comfortable 72 degree temperature on scorching 114-degree days.

"Energy consumption can vary greatly from one tiny house

to another," says Vivien Luo, engineering and construction management professor at California State University, Fresno. Luo leads the Fresno State Tiny House Project, a hands-on learning experience where students build a net-zero-energy 190-square-foot tiny home. "It depends on the mechanical and electrical systems used to power the house and the appliances inside the house," she says.

Over 2,500 miles east of Boise in Vermont, Murphy Robinson opted for a wood stove in her ultra-tiny home. She has lived in just 72 square feet for over three years. "Theoretically, I could harvest my own wood for the winter sustainably from the lot where I live," she says. "I really like the relationship with the land."

Her 5.5-foot by 13-foot space isn't only her home—she also runs her business, Mountainsong Expeditions, out of it. She leads wilderness-based expeditions, courses on ethical hunting and archery, and even a women's trail running archery course.

While she saw a huge drop in energy consumption when she transitioned to her tiny home, the downside is that the cabin freezes when she's not stoking the fire. "I don't have any frost-free space, and it won't stay warm if I'm not there," she says. She keeps items that can freeze in the cabin and stores perishables, such as olive oil, with a friend.

The cooler and ice pack she used in lieu of a refrigerator for her first two years in the tiny house, didn't work as well as she'd hoped. "On hot days, even when I changed the ice pack every day, I was still throwing away kale after a day and a half," she says. Now she uses a small refrigerator hooked up to a nearby solar panel, but she still finds the woodstove's warmth affects the shelf life of her perishables.

While not everyone would want to live in 72 square feet and deal with frozen olive oil and wilting kale, the tiny home principles of living lightly on the land, reducing debt, and minimizing energy consumption in an era of climate change have sparked wide interest. For example, the 2016 Tiny House Jamboree in Colorado, with three days of speakers, workshops, films, and tiny home viewings, drew 50,000 attendees.

While moving into a tiny house can reduce a person's energy consumption and carbon footprint, living simply also reduces a different type of energy expenditure: the amount of time and effort needed to afford and maintain a massive home. Robinson finds it hard to store just about anything in her 72-square-foot structure. With only one five-foot-long bookshelf, she doesn't acquire many material possessions. For every item she acquires, she typically has to part with something else.

"Overall, I'm pretty immune to the allure of knick-knacks because there's nowhere to put them," she says. This also saves energy, since less is required to produce, transport, and sell these items.

While technological fixes, such as LED lights, solar panels, and hybrid cars, can reduce carbon footprints and energy consumption, the simplest and most effective path may simply be to downsize.

Kristen Pope *is a freelance writer and editor who covers science, conservation, outdoor recreation, and travel.*

Courtesy Murphy Robinson

Murphy Robinson sits in the kitchen of her tiny home on wheels.

While technological fixes, such as LED lights, solar panels, and hybrid cars, can reduce carbon footprints and energy consumption, the simplest and most effective path may simply be to downsize.

Amphibious Citizen Scientists

Citizen scientist Jerod Merkle scoops up a tiger salamander in Wyoming's Sierra Madre as part of the Rocky Mountain Amphibian Project.

Wildlife managers turn to volunteers for help collecting hard-to-get data

Text and images by Bethann Garramon Merkle

I swished my dipnet through water and vegetation at the edge of the beaver pond, creating swirls of mud that obscured the bottom. Lifting the net created a moment of suspense. I sorted through pebbles, aquatic plants, caddisfly cases, and the occasional minnow, hoping to spot a tadpole. I'd been zigzagging and dip-netting through waist-high grass, dense willows, and standing water all morning. No luck.

Then, as I shook pond detritus from the net, I heard a shout of glee. In the stream at the foot of a beaver dam, my husband, Jerod, grinned wildly and held up a net oozing mud. In his grasp was the first salamander either of us had seen in the wild. The catch was exhilarating, but we weren't out there just for fun. We were collecting data on sensitive, hard-to-track species and helping change the paradigm of how long-term amphibian monitoring and conservation is done throughout the Mountain West.

In 2006 the US Fish and Wildlife Service considered a petition to list western populations of the northern leopard frog as an endangered species. The agency needed population information, but Wyoming was a bit of a blank. Zack Walker, then the state herpetologist, remembers, "When we started going back through our data, we realized we didn't have anything." He found only a few studies, and they were limited in geographic scope and lasted no more than two to three years, too short to determine whether a population is in decline. Reinforcement came in 2008, when the Wyoming Natural Diversity Database (WYNDD) hired Wendy Estes-Zumpf as a staff biologist, and she took over their amphibian

projects. She was "just shocked," she says. "We knew hardly anything about the populations, not even where some of them did and didn't occur."

So, Estes-Zumpf and Walker got to work surveying the Bighorns and other mountain ranges across Wyoming. They figured out which species were present there, but they were nowhere close to understanding population trends statewide. In 2011, the duo partnered with three national forests: Wyoming's Medicine Bow and Bridger-Teton, and the Routt in Colorado. For the next two years, biologists and technicians with the partner agencies surveyed amphibians. But when Estes-Zumpf calculated the minimum data needed to detect trends in state amphibian populations, she found more areas would need to be surveyed "than the Forest Service could reliably fund every year, even with help from WYNDD and Game and Fish."

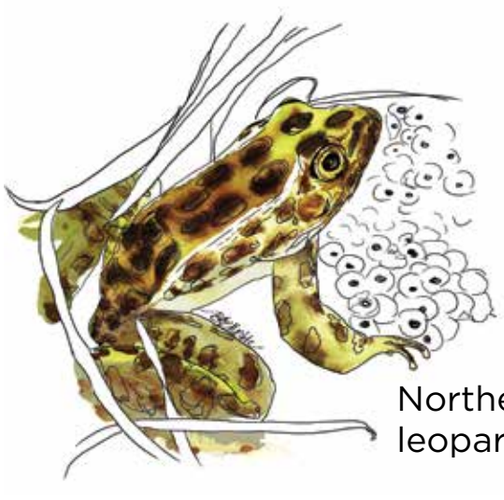
Then came a happy accident. In late 2012, Estes-Zumpf gave a presentation about the project to the Wyoming chapter of The Wildlife Society and made a plea for more agency volunteers. She recalls that Carlos Martinez Del Rio, director of the then freshly minted Biodiversity Institute (BI), "comes running over in the dark, crouches down right next to my chair as the next speaker starts. And he says, 'We need to talk. This is a great flagship project for the new BI.'" He thought citizen volunteers could be recruited to help collect data.

This was a new idea for Estes-Zumpf. Volunteers might bolster much needed data collection efforts without costing a lot. If the idea worked, the BI would have a compelling science education and outreach project, and WYNDD and Game and Fish would have enough data to monitor population trends.

Thus, out of a combination of inspiration and desperation, Walker and Estes-Zumpf teamed up with the BI to create the Rocky Mountain Amphibian Project (RMAP). Citizen science, which has gained momentum over the past decades, entails members of the general public collaborating with professional scientists to collect or analyze nature-related data. In the case of RMAP, volunteers collect the same data as biologists and technicians, despite far less specialized training or experience.

In most such projects, a key individual connects public volunteers with the science. When RMAP started, that was Brenna Marsicek, Outreach Coordinator at the Biodiversity

ROCKY MOUNTAIN AMPHIBIAN



Northern leopard frog

Boreal chorus frog

Wood frog

Institute. Hers was no small task. She was a media wrangler, a social media strategist, a website designer, and a volunteer recruiter. With plenty of space to experiment and dream, Marsicek and Estez-Zumpf asked for a lot of advice and invented as they went along. "Brenna and I have run ourselves ragged," Estes-Zumpf says, "but we both love the project." Their enthusiasm rubs off on volunteers. In 2016, citizen scientists comprised 90 percent of the people collecting data. Dozens of volunteers from across Wyoming sign up each year, for two main reasons. Marsicek says, "It's just fun. It brings out the kid in you." And Estes-Zumpf has heard from many of the volunteers who return that they appreciate "that they are doing real hardcore scientific surveys."

That's why Jerod and I signed up in 2015. We were curious about amphibians, and both of us had worked on other field research projects in the past. We jumped at the opportunity to learn more by contributing to RMAP. At our full-day training in May, Estes-Zumpf introduced us and about twenty other volunteers to our target species and the data collection methods we would use. We started in a classroom and concluded with a couple of hours stalking loudly mating frogs in a pond brimming with their egg masses. We were hooked.

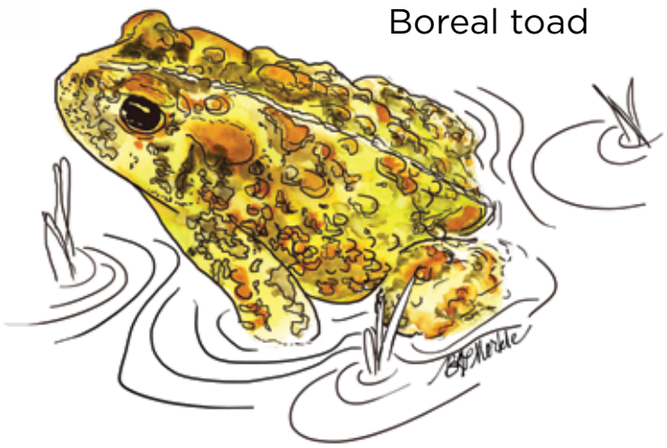
We spent a Saturday in June and again in July surveying a catchment—a designated survey area comprising prime amphibian habitat—in southern Wyoming's Sierra Madre. That season, the survey involved working uphill from some old, grown-in beaver ponds, along a slender rocky creek, to another set of inactive beaver ponds. The next summer we returned for two more surveys in another catchment

containing active beaver ponds, tiny streams, a spring seep on a hillside, and a lot of wet meadows. We started our surveys around eight o'clock in the morning, and finished in four to six hours. We were looking for six species: tiger salamander, boreal toad, northern leopard frog, wood frog, Columbia spotted frog, and boreal chorus frog. The general idea is to check likely amphibian habitat at 24- to 30-foot intervals. And so we spent the day whipping dip nets back and forth to create vortices, which slow and disorient amphibians, making it easier to scoop them from the now-opaque water. Outside of standing water, we crept along slowly, trying to spot adult

PROJECT TARGET SPECIES

Columbia spotted frog

Tiger salamander (tadpoles)



Boreal toad

frogs and toads. Weaving across the catchment, we watched the grass for leaping shadows. Most of the adults we found were small and dark enough to seem like they morphed out of the mud and clumps of grass we disturbed.

When Jerod netted that tiger salamander, morning light caught its skin and its holographic stripes flickered. Jerod held it near its armpits, trying not to drop or crush it. He wore pistachio-colored latex gloves to protect the animal's slippery skin from sunscreen, bug dope, and the oils on human skin. The gloves contrasted against the salamander's olive-gray body. Its protruding eyes cast shadows toward its nostrils. Its mouth seemed set in a perpetual smirk. I took a couple of photographs, then ran a cotton swab across the insides of its legs and dropped the swab into a pinkie-finger-sized vial of ethyl alcohol. Estes-Zumpf would send that swab to be tested for chytrid, a fungus devastating amphibians across the continent. Then Jerod eased the salamander back into the murky water while I marked our location with a GPS. As he shook loose the mud and debris in his net, I pulled out the RMAP data sheet. I jotted down the salamander's age (adult), location, and the local habitat (perennial stream).

Downstream, it was my turn to whoop, as I fished out two salamander tadpoles with fringed algae-green gills forming translucent manes around their necks. Young salamanders mean evidence of breeding, suggesting a viable population. We identified these as tiger salamanders, the only species of salamander in Wyoming.

Later, I caught some frog tadpoles. They were too small for me to determine their species. Following protocol, I dropped one into another vial of ethyl alcohol, to return to Estes-Zumpf.

Unidentifiable specimens are just one of the unknowns Estes-Zumpf has faced since founding RMAP. More challenging are the questions that don't have straightforward answers. What if registered volunteers don't show up? Or don't come back year after year? Above all, what if the data volunteers collect isn't good enough?

Volunteers are cheaper than hiring additional employees, but ineffective training, insufficient attention to detail while surveying, or lack of thoroughness in completing data forms could lead to unusable data. Estes-Zumpf is candid: "If resource agencies are going to make management decisions that they could get sued for, based on data that's collected by a whole suite of different people," the data must be defensible.

She needed to know: were RMAP volunteers collecting reliable data? In 2014 and 2015, she put them to the test. She sent Game and Fish biological technicians to several sites volunteers also surveyed those seasons. Citizen scientists were slightly less successful with hard-to-detect species, such as boreal chorus frogs and bottom-dwelling salamanders. Now that she knows that, Estes-Zumpf can account for these lower detection rates when analyzing the data. Otherwise, results were comparable between the citizen scientists and professional biologists. It appears RMAP can rely upon this citizen science data, thanks in large part to thoroughly training volunteers.

Citizen scientists have expanded the scope of RMAP data collection significantly. "For the first time for some areas," Estes-Zumpf says, "we have five years of trend data for a whole suite of species." There have been a couple of surprises so far, such as low species diversity—almost exclusively boreal chorus frogs—in the Wind River Range and no wood frogs in the Sierra Madre. This winter, Estes-Zumpf will analyze those data to determine which, if any, montane amphibians are declining. She hopes "this monitoring program will allow us to catch problems early and deal with them quickly before more serious management or recovery efforts are needed."

Ideally, RMAP will meet this need and then some. Since the beginning, RMAP partners have aimed to expand into other mountain ranges in Wyoming and even into adjacent states. They have also begun discussing collaborating with other agencies, such as the Bureau of Land Management. If such a partnership develops, RMAP might extend to lower-elevation habitats. Estes-Zumpf sees these partnerships as a blend of optimism and pragmatism: "There's a lot of interest, as funding gets tighter, in having citizen scientists help us figure out what's going on out there on the landscape."

In this sense, we citizen scientists are also amphibious: "having two modes of existence," or "living a double life." Much as frogs spend part of their lives breathing through gills underwater and part of their lives breathing through lungs, we engage amphibian research at a threshold between science and recreation. And, being an RMAP volunteer transforms outdoor experiences into a blend of rigor and emotion.

Near the end of my second survey, I caught an inch-long boreal chorus frog hopping through damp grass. The frog and I stared eye to eye. It crouched on my latex-gloved palm. I could see its heart throbbing. Green and gray spots rapidly stretched and relaxed on mottled skin. As the frog's toes clutched the curve of my thumb, RMAP's solution to a major data collection dilemma made sense.

Bethann Garramon Merkle *is an illustrator, science writer, and educator. Her work has been commissioned and published by entities including* Parks Canada, The Nature Conservancy, American Scientist, *and* Montana Outdoors.

Support science storytelling and informed natural resource management decisions

THANK YOU TO OUR GENEROUS SUPPORTERS

Western Confluence magazine would not be possible without generous contributions from readers like you. We produce two beautiful and informative issues each year with a very small staff. Donations of any size go to paying the freelance writers and photographers we work with, as well as our graphic designer and web developer. These gifts also cover our printing and mailing expenses. A special thanks goes out to the readers who have contributed to this publication.

In particular, this energy issue was funded by gifts from Richard and Mary Lou Taggart, the Ordway family, and the Walton Family Foundation. We'd also like to recognize Julia Bounds, Michael and Joyce Evans, Charles Kirkham, Jenny Wright and Stan McCumber, and Ruby Quarterman for contributing to the magazine.

GIVING IS EASY

Cut out this form and send it with your contribution in the mail:

University of Wyoming Foundation
222 S 22nd St
Laramie, WY 82070

Call the UW Foundation at (888) 831-7795, or click the donate button at westernconfluence.org.
Please specify that your gift supports *Western Confluence* magazine and reference giving code P17WW.
Your gift is tax deductible as provided by law. Thank you for your support.

✂- -

Help us share stories of critical natural resource research findings with citizens and decision makers nationwide. We need your support. Your contribution will underwrite thoughtful, compelling, articulate articles to inform natural resource management.

☐ Yes, I'll support rigorous science reporting to inform sound natural resource management.

My gift to *Western Confluence* magazine:

☐ $100 ☐ $250 ☐ $500 ☐ $1,000 ☐ Other____________

Name(s) ____

Address: ____

City: ____________________ State: ____________ Zip: ____________

Phone: ____________________ Email: ____________________

GIVING CODE P17WW

COLLABORATIVE SOLUTIONS

A Program of the Ruckleshaus Institute of Environment and Natural Resources at the University of Wyoming

"People affected by change have to be deeply involved in the crafting of solutions... We have to get better at both involving people in the process of change and providing them with enough information to make that involvement useful and worthwhile."

-- William D. Ruckelshaus

Collaborative approaches are more necessary than ever. We bring stakeholders together to build robust, informed, inclusive solutions to our most complex and controversial natural resource challenges.

Learn more at UWYO.EDU/HAUB/RUCKELSHAUS-INSTITUTE

UNIVERSITY OF WYOMING

HAUB SCHOOL OF ENVIRONMENT AND NATURAL RESOURCES

News and Goings On

Happenings of potential interest to Western Confluence *readers*

FAREWELL TO OUR FOUNDING PUBLISHER

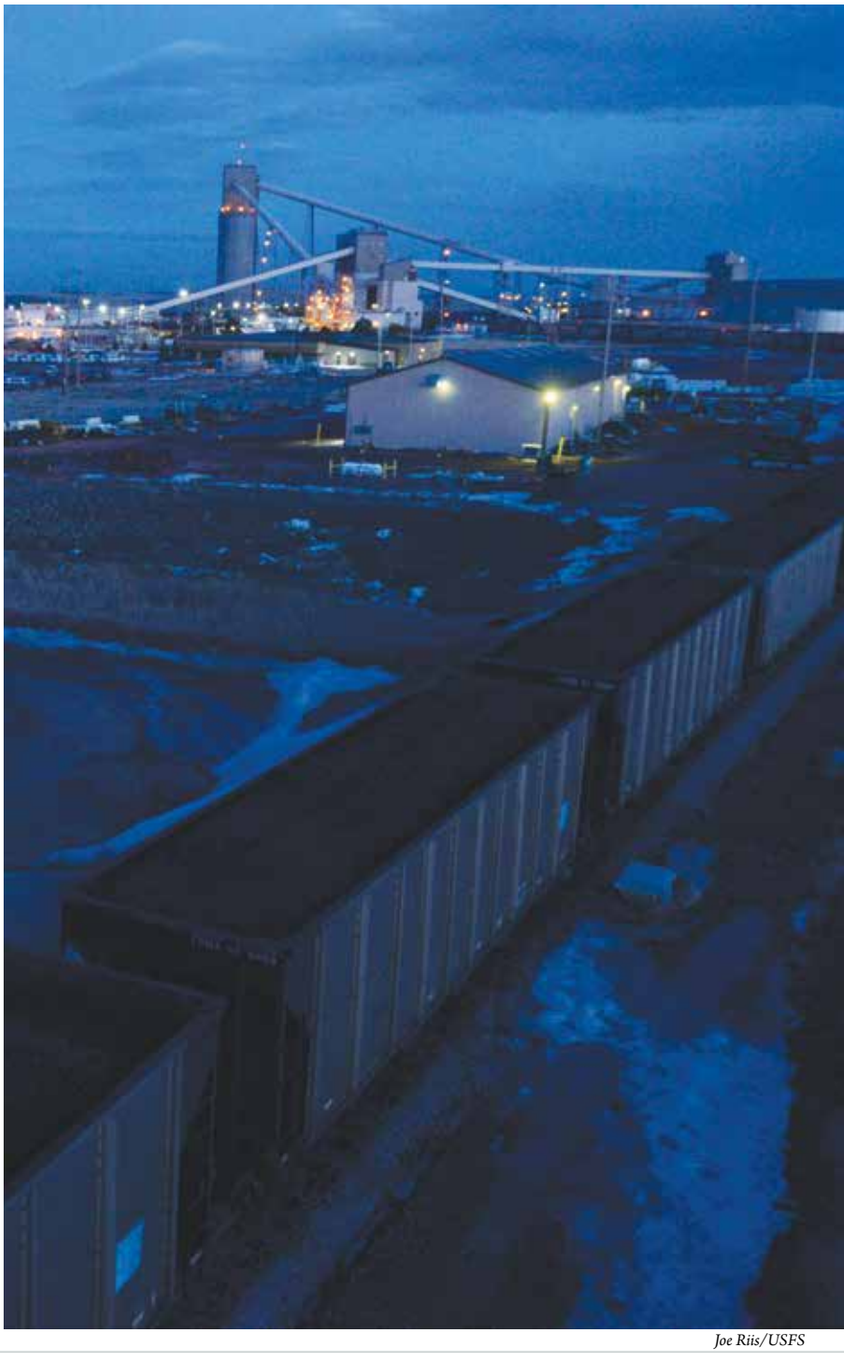
When Dr. Ingrid Burke took the position as director of the Haub School and Ruckelshaus Institute of Environment and Natural Resources back in 2008, one of her ambitions was to create a "journalzine." This would be a hybrid publication with the rigor, credibility, and information density of a scholarly journal, and the accessibility of a popular magazine.

We released our first issue in the winter of 2014. Since then, *Western Confluence* has developed into a trusted resource, giving readers a window into natural resource research, legal analyses, and other work happening at universities and on the ground around the western United States.

In 2016, after shepherding the publication of our first six issues, Dr. Burke accepted a position as Dean of the Yale School of Forestry and Environmental Studies. As we search for her replacement, we can only hope that the next Haub School leader will be as visionary and supportive of science communication as Dr. Burke.

WYOMING PUBLIC LANDS INITIATIVE FACILITATION

The Wyoming County Commissioners Association invited Steve Smutko, Spicer Chair for Collaborative Practice in the Ruckelshaus Institute, to assist in developing a collaborative process for the Wyoming Public Lands Initiative. The WPLI is an effort to develop a locally led, Wyoming-specific, legislative lands package that will address designation, release, or other management for Wilderness Study Areas. As WPLI has progressed, two Wyoming counties—Teton County and Sublette County—asked our Collaborative Solutions Program staff to facilitate their committees working on this initiative.



Joe Riis/USFS

WYOMING OPEN SPACES INITIATIVE

The second installment in the Wyoming Open Spaces Initiative's Land-Use Planning Series in now available from the University of Wyoming. "Local Government Land-Use Planning in Wyoming," by UW researchers Jeff Hamerlinck and William Gribb, provides information to help empower Wyoming citizens to become part of the land-use planning process in their local communities.

"The most effective land use planning is intentional and reflects the interests of local communities and their citizens," said Hamerlinck. "Land-use planning is integral to creating prosperous communities by shaping how towns and counties grow and develop."

The goal of the Wyoming Open Spaces Initiative's Land-Use Planning Series is to provide information and resources to support citizen participation in local planning processes. The first publication in the series focused on Wyoming's land-use patterns and development trends. Future bulletins in the series will address topics like the legal foundations of planning in Wyoming, traditional land development controls, and innovative land-use planning techniques.

The Wyoming Open Spaces Initiative is a collaborative effort of the Ruckelshaus Institute of Environment and Natural Resources, the Wyoming Geographic Information Science Center, the Department of Agricultural and Applied Economics, the Department of Geography, University of Wyoming Extension, and the Wyoming Natural Diversity Database. The initiative supports Wyoming citizens' maintenance of the state's open spaces through research, information, education, and decision-making assistance. For more information, visit uwyo.edu/haub.

Case of the Missing Otters

UW researchers search for answers in the Green River Basin

By Kristen Pope

Brady Godwin was on the lookout for river otters. In 2010 and 2011, he floated by raft down southwest Wyoming's New Fork River, the Upper Green River above Fontenelle Reservoir, and the Green River within Seedskadee National Wildlife Refuge, searching for signs of otters. Only a few western US watersheds—including the Green River and its tributaries—are home to these members of the weasel family. As a University of Wyoming graduate student, Godwin's aim was to survey otter distribution within the Green River Basin to obtain baseline numbers so he could analyze how expanding energy development affected the species.

"We wanted to see where they were," Godwin explains. "There wasn't a lot of historical information about them in the area."

He didn't expect to see many of the reclusive animals, but he thought he'd see plenty of signs, such as scat. The area was prime otter habitat with plenty of fish. He searched for otter latrines—shared defecation sites—and marked each one by GPS. He searched for fresh otter scat at every latrine 12 times during each year and used hair snares at high-activity locations to collect hair samples for DNA analysis.

While both the Green River and the Upper Green River showed about the number of animals expected in such prime otter habitat, otters were conspicuously absent from the New Fork River.

"I found the occasional otter scat but nothing at all that would indicate persistent resident populations," Godwin says of the New Fork River. His advisor, University of Wyoming wildlife ecology professor Merav Ben-David, even brought her otter-sniffing dog to investigate. When the dog couldn't find evidence of otters either, they began to wonder why.

The absence of otters in the New Fork River was especially concerning because they are top predators in freshwater ecosystems. They control populations of fish, crayfish, and other aquatic animals and keep the ecosystems healthy by not letting populations get out of control.

According to Ben-David, otters eat the equivalent of 10 percent of their body mass in fish each day, and that means toxins and heavy metals the fish might have consumed build up in the otters. This process, called bio-accumulation, can have a number of negative effects on otters including reproductive problems and death. Their sensitivity to environmental degradation, human-caused disturbances, and pollution makes them a "sentinel species," a harbinger of potential water quality threats that could affect humans.

Courtesy Brady Godwin

The Green River in the Seedskadee National Wildife Refuge.

In order to figure out what was keeping otters away from the New Fork River, the scientists gathered data on several environmental factors. "We were immediately thinking of possible explanations for river otter absence—energy development being one of them—but [we] also looked at potential food, general habitat quality, disturbance, and anything we brainstormed that might be affecting the otters," Godwin says. They obtained fish counts from the Wyoming Game and Fish Department to see if the otters had an adequate food supply. To test whether disturbance was harmful to the animals, they compiled observations, aerial imagery, and GIS data including roads, power lines, buildings, and other forms of development. They also gathered information about potential noise and light disturbances. They wanted to examine every potential reason otters weren't present, narrowing down the possibilities one by one.

Courtesy Brady Godwin

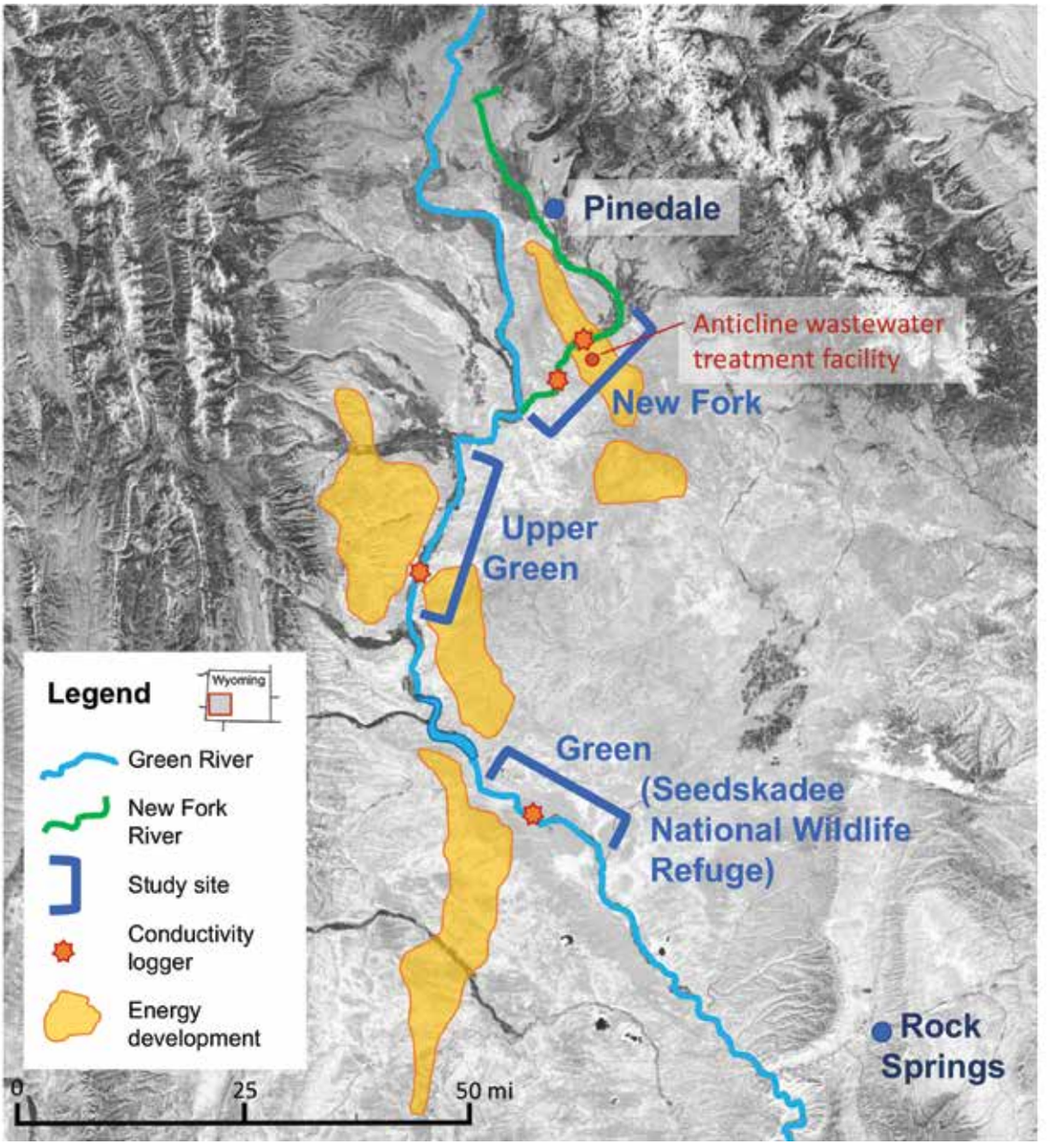
Researcher Brady Godwin rows to one of his study sites.

Next, they used electrical conductivity loggers at four sites to indirectly test for pollution. One logger was above the Pinedale Anticline energy development field. The next was below a wastewater treatment facility that processes high-saline waste fluids from hydraulic fracking. The other two were further downstream, in the Upper Green River and wildlife refuge sections of the study area. The scientists logged conductivity levels daily from July through November in 2012.

All three stretches of river had similar habitat and food available, but Godwin's calculations showed more disturbance along the New Fork River than in other locations. Furthermore, in September, they found a large increase in conductivity—1.6 times the expected amount—downriver of the wastewater treatment facility. Readings taken at the same time above the facility showed normal levels. The researchers didn't find any runoff, changes in river hydrology, or other explanations for the findings.

"We don't know what was actually creating that charge," Godwin says.

The researchers did not have the resources to detect specific compounds in the river at the time, and they cannot definitively say why otters are absent from the New Fork River, though they wrote in their peer-reviewed article about the study, "otters appeared to avoid areas near energy development." They are currently seeking funding to re-sample the Green River, collect water samples to identify compounds that may explain the abnormal conductivity, and expand the study to the Wind River, Big Horn, and Platte watersheds further east in Wyoming.



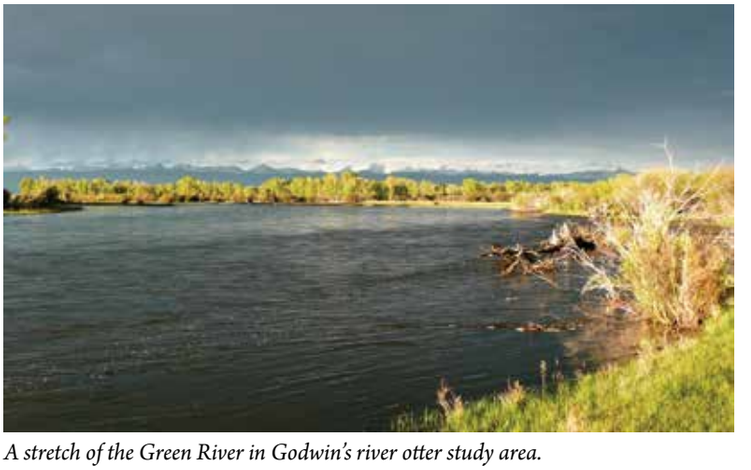
Brady Godwin's river otter study area spanned stretches of the New Fork and Green River passing by natural gas fields in southwest Wyoming.

"We don't have a smoking gun or anything," Godwin says. "We just have some pretty strong evidence that what might be affecting the otters might not be a perfectly natural process."

FURTHER READING

B. Godwin, S. Albeke, H. Bergman, A. Walters, and M. Ben-David. "Density of river otters (Lontra candensis) in relation to energy development in the Green River Basin, Wyoming." *Science of the Total Environment* 532 (2015) 780-790. doi:10.1016/j.scitotenv.2015.06.058

Courtesy Brady Godwin



A stretch of the Green River in Godwin's river otter study area.

Small-Scale Hydropower

Wyoming's streams and irrigation ditches are an untapped clean energy source

By Robert Waggener

"If we disconnected that 14-inch pipe and pointed it upward, the water would blast nearly 600 feet into the air," says Les Hook over the loud hum of the hydro turbine.

Of course, the City of Buffalo public works director would land in jail if he pulled a stunt like that, but his scenario reveals just how much water pressure it takes to turn the 225-kilowatt turbine housed in a mostly underground concrete bunker at the foot of the Bighorn Mountains in north-central Wyoming.

"That turbine is breaking about 250 pounds per square inch of water pressure down to zero," Hook says. "That's a heck of a lot of thrust!"

Buffalo, like a growing number of utilities, electric coops, municipalities, irrigation districts, and agricultural producers across the West, is using water and modern technology in the form of hydro turbines to generate "green" electricity. In particular, small-scale hydropower—those projects that produce less than five megawatts of electricity—can provide reliable, low-carbon, renewable energy for decades. And in a mountainous state like Wyoming, with plenty of streams and irrigation canals flowing downhill, the potential for additional small-scale plants like the one in Buffalo is anything but small.

At the Buffalo facility, nearly 50 gallons of water per second have blasted down a pipeline and into the Pelton turbine since going online in 1998, churning out enough juice to power about 150 homes in the regional grid. Electricity is sold to Rocky Mountain Power, and since the turbine was built to last 100 years, the city stands to profit on its long-term investment. But the Buffalo project never would have come to be without a loan from the Wyoming Water Development Commission. Even small projects like this one cost hundreds of thousands of dollars to build and take years to pay off. The state can play a role in incentivizing this clean energy source by pulling together funds from a variety of sources, including state, federal, and private, among others.

Robert Waggener

Les Hook, public works director in Buffalo, Wyoming.

Vance Fulton/NRCS

Hydro-powered center-pivot on a ranch in Colorado.

For ideas on how to promote hydropower development, Wyoming might look to its southern neighbor, Colorado, where a hydropower movement is gaining speed. The US Department of Agriculture's Natural Resources Conservation Service (NRCS) recently awarded a $1.5 million grant to the state to help fund small-scale hydro projects on ranches and farms to address water quantity, water quality, and energy resource concerns.

An additional $1.5 million came from the state and a host of partners, including American Rivers, Hydro Research Foundation, The Nature Conservancy, and Rocky Mountain Farmers Union as well as a number of Colorado energy, water conservation, rural electric, and hydro boards and associations.

"Since Colorado enacted the citizen-led Renewable Energy Standard in 2004, the state has been very progressive in promoting renewable energy projects," says Sam Anderson, Colorado Department of Agriculture energy specialist. He is overseeing the $3 million in grants that will help fund about 30 hydro-mechanical and hydro-electric irrigation systems in the state over the next three years. Colorado's Renewable Energy Standard, the first voter-led initiative of its kind in the nation, requires investor-owned utilities (currently Xcel Energy and Black Hills Energy) to generate 30 percent of their electricity from renewable energy by 2020, including

> "Wyoming has great renewable energy resources, including hydropower, and the state can put that to work for the betterment of the people and the environment. It just takes a local champion to get that going."
>
> *Milt Geiger*

Sam Anderson, Colorado Department of Agriculture energy specialist.

3 percent from small-scale energy resources such as hydro, solar, and wind. The 22 rural electric cooperatives, meanwhile, must generate 20 percent of their electricity from renewables by 2020.

In addition to the Renewable Energy Standard, concerns about flood irrigation are also motivating the push for hydro in the state. "We use the hydro power as an incentive to encourage farmers and ranchers to engage in more efficient irrigation practices," Anderson says. Converting from flood irrigation to center pivots saves water and reduces leaching of salts and selenium into waterways. Grants pay about 70 percent of the total project costs on farms and ranches, while ag producers fund the rest. Among those jumping on board is Susan Raymond, who operates a farm and veterinary practice in west-central Colorado near the small mountainous community of Hotchkiss.

Raymond was awarded grants from NRCS and the Regional Conservation Partnership Program to help install a hydro-electrical system and two center pivots, which collectively replaced labor-intensive flood irrigation and are helping her to grow better crops with less water. Produced electricity not only runs the pivots, but also her veterinary facilities, and any surplus goes into the power grid.

Colorado is playing a central role nationally in advancing small and micro hydropower, Anderson says. Working with NRCS and other partners, the state is developing an innovative program, and there is tremendous potential in other states to develop hydropower as well.

≈

"Wyoming has great renewable energy resources, including hydropower, and the state can put that to work for the betterment of the people and the environment. It just takes a local champion to get that going," says Milt Geiger, who served for six years as energy coordinator for University of Wyoming Extension and the UW School of Energy Resources. In 2016 he took a new job as the first alternative energy administrator for Poudre Valley REA, a non-profit rural electric association based in Fort Collins, Colorado.

During his time in the Cowboy State, Geiger co-authored the *Wyoming Small Hydropower Handbook* and hit the state's highways to promote the publication and meet with citizens interested in small-scale hydro development, including those who operate farms, ranches, and irrigation districts.

Cindy Lair/Colorado Department of Agriculture

Susan Raymond checks her farm's hydropower system.

The handbook states that hydroelectric installations are the most common and often least expensive sources of renewable electricity in the United States today. That's appealing in a time when interest in low-carbon-emissions energy is escalating. But sizeable hydropower plants—notably those in dams backing up large rivers—come with their share of environmental problems and associated opponents. That's why Geiger and his co-authors wanted to share information about small-scale hydro, which can be built into existing small dams or other infrastructure associated with irrigation districts. If designed properly, such projects can protect surrounding ecological values such as river flows, water quality, and fish and wildlife habitat.

One of Geiger's co-authors, Skylor Wade, works for the Cheyenne engineering firm Wenck and Associates, which recently designed a new hydroelectric facility to run the city's Sherard Water Treatment Plant. Construction of the 700-kilowatt unit begins in early 2017, and the plant is expected to be online in 2018. "I think there is a tremendous amount of potential for small-scale hydro in the state, but it will take support from a lot of people, including legislators and the Wyoming Public Service Commission," Wade emphasizes.

Back at the Buffalo plant—where the thick, heavily reinforced concrete floor vibrates under Les Hook's boots as water roars into the Pelton turbine—talk turns from pounds per square inch and kilowatt hours to the attitudes of people and our energy future.

"Yes, I definitely believe in promoting green energy," emphasizes the public works director. "But it's going to take action by legislators, public service commissioners, and utilities, to name a few. If a movement gets going, I believe renewable energy in our state, hydro included, will begin to fly."

Steve Miller/UW Extension

Milton Geiger, Poudre Valley REA alternative energy administrator.

***Robert Waggener** is a Laramie, Wyoming-based editor, writer, and photographer focusing on agriculture, natural resources, and science in Wyoming and the West.*

FURTHER READING

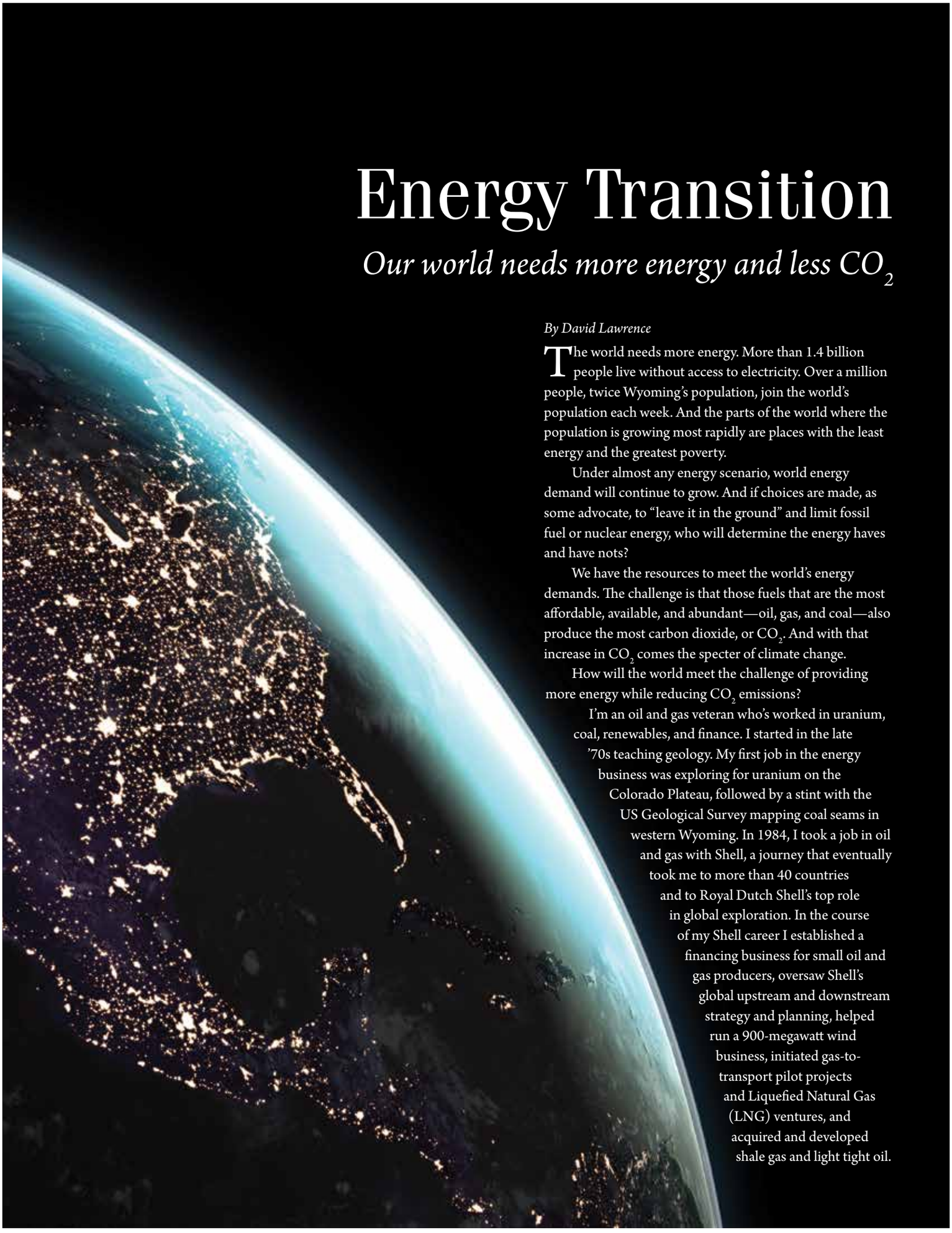
ACRE3: Agricultural Hydro. Colorado Department of Agriculture. 2016.

Hydro Power Vision: A New Chapter for America's 1st Renewable Electricity. US Department of Energy. 2016.

Milton Geiger, Sarah Hamlen, and Mike Vogel, editors. *E3A: Micro-Hydropower for the Home, Farm, or Ranch.* University of Wyoming Extension, Montana State University Extension, and Western Sustainable Agriculture Research and Education. 2016.

Skylor Wade, Dylan Wade, and Milton Geiger. *Wyoming Small Hydropower Handbook.* University of Wyoming Extension Bulletin 1262-1. 2015.

Find links to these documents at westernconfluence.org.



Energy Transition

Our world needs more energy and less CO_2

By David Lawrence

The world needs more energy. More than 1.4 billion people live without access to electricity. Over a million people, twice Wyoming's population, join the world's population each week. And the parts of the world where the population is growing most rapidly are places with the least energy and the greatest poverty.

Under almost any energy scenario, world energy demand will continue to grow. And if choices are made, as some advocate, to "leave it in the ground" and limit fossil fuel or nuclear energy, who will determine the energy haves and have nots?

We have the resources to meet the world's energy demands. The challenge is that those fuels that are the most affordable, available, and abundant—oil, gas, and coal—also produce the most carbon dioxide, or CO_2. And with that increase in CO_2 comes the specter of climate change.

How will the world meet the challenge of providing more energy while reducing CO_2 emissions?

I'm an oil and gas veteran who's worked in uranium, coal, renewables, and finance. I started in the late '70s teaching geology. My first job in the energy business was exploring for uranium on the Colorado Plateau, followed by a stint with the US Geological Survey mapping coal seams in western Wyoming. In 1984, I took a job in oil and gas with Shell, a journey that eventually took me to more than 40 countries and to Royal Dutch Shell's top role in global exploration. In the course of my Shell career I established a financing business for small oil and gas producers, oversaw Shell's global upstream and downstream strategy and planning, helped run a 900-megawatt wind business, initiated gas-to-transport pilot projects and Liquefied Natural Gas (LNG) ventures, and acquired and developed shale gas and light tight oil.

This on-the-job education across the energy spectrum in industry, government, and academia instilled a healthy dose of pragmatism in my thinking about our energy and climate challenges. Despite the welcome and remarkable growth of renewable electricity generation, fossil fuels still provide more than 82 percent of the world's primary energy—what we use to move our planes, trains, and automobiles; heat, cool, and light our homes; fuel our factories; manufacture our products; farm our fields; and power our communities, schools, hospitals and businesses. Energy, including fossil fuels, has been, is, and will be a force for good. As Elon Musk, head of the electric vehicle company Tesla said about oil and gas, "If we didn't have them, we would have economic collapse and people would be starving to death."

Transitioning to lower CO_2 energy sources is not easy. Energy is not microchips where significant rates of new product penetration are measured in quarters and years. Market penetration of new energy sources is typically measured in decades. It took almost 70 years for coal, 65 years for oil, and more than 80 years for natural gas to garner a 20 percent market share of the world's energy. Today, nuclear still only supplies about 5 percent of the world's primary energy supply. Despite massive cost reductions, tax credits and subsidies, wind and solar are still less than 3 percent of the global energy mix. "Zero-carbon" electricity's percentage of total global electricity supply has been decreasing the past decade as nuclear power plants have been shut down and new coal-fired power plants are installed. And despite great advances in electric vehicles, more than 80 million new gas and diesel automobiles are still purchased each year, and each has an average life of over a decade. CO_2 emissions continue to grow.

As we seek solutions, recognize that there is a cost for everything. An implementable vision for our energy future requires a shift in mindset to move beyond that of the theoretical fabulist. The world will need all the energy that it can get, and that energy comes with tradeoffs—CO_2 and particulates from fossil fuels; perceived radiation risk and waste storage from nuclear; reliability, footprint, and distribution for wind and solar; land use and ecological disruption from hydro. "Not in my backyard" for all.

An ideal energy system would be affordable, abundant, available, safe, secure, and sustainable, with low emissions and a small footprint. Price, reliability, and scalability matter. Costs must allow economies to grow at a sustained pace and be competitive with existing energy sources.

Nothing is perfect. No single energy source meets all these criteria. Instead, we should embrace a portfolio of diverse energy sources, conservation and efficiency measures, technology research and development, and CO_2 mitigation projects that merit action now. What might this portfolio include?

On the supply side, natural gas power plants provide affordable, reliable baseload power generation with half the CO_2 of older coal-burning power plants. Cost reductions have made wind and solar more commercially attractive in many regions and hydropower has long competed as a low-cost, zero-carbon energy source. New transmission infrastructure and smart grids will be essential to increasing power reliability and expanding renewables. Nuclear energy, including new modular technologies, brings significant advantages of scale. The importance of existing nuclear facilities should not be underestimated. For example, the Diablo Canyon nuclear power plant in California, a candidate for early shutdown, contributes twice as much power as all the solar panels in California. That's a lot of zero-carbon electricity.

An ideal energy system would be affordable, abundant, available, safe, secure, and sustainable, with low emissions and a small footprint.

Energy conservation and efficiency is one of the best ways to assure there is enough energy to go around while lowering CO_2 emissions and saving money. Pathways available to us now include energy-efficient appliances, heating, cooling, lighting, and building materials; innovative architectural and urban design; retooled and redesigned manufacturing and industrial processes; accessible public transportation; fuel-efficient transportation (including electric vehicles); and much more.

We need a giant step change in energy research and development. US government support for energy R&D is anemic, about one-third of what it was during the energy crisis of the 1970s. Bill Gates and others have called for a "moonshot" approach to solving our energy dilemmas. Of particular interest to Wyoming is research and development in carbon capture, storage, and utilization and negative emissions technologies, both crucial to achieving lower CO_2.

There should be many opportunities for new industrial-scale energy pilot projects in Wyoming, including carbon capture and usage for coal. Support for wind (which Wyoming is blessed with in abundance) and solar, will continue to grow as costs are increasingly competitive and reliability is improved. What is the potential for natural gas in transport and manufacturing? How can electric and fuel-efficient vehicle use be expanded? Wyoming, building on programs and initiatives at UW and partnerships with industry, could lead energy research and development.

Meeting the energy transition challenge will not be easy. Bipartisanship, disengagement, and divestment are not solutions. It's a time for action, partnerships, and investment across the entire energy sector. The challenge of energy and climate may lead to setbacks and to cynicism in some. But others, Wyoming included, should see enormous opportunities for individuals, business, and society and step up to lead.

David Lawrence *is a University of Wyoming 2016 Energy Law and Policy Fellow. He is Chairman of Lawrence Energy Group, LLC, a firm investing in emerging stage energy opportunities. Lawrence received his PhD in geology and geophysics from Yale University, is past chairman of the advisory board of the Yale Climate and Energy Institute, and retired as an Executive Vice President of Shell after a global career spanning three decades.*

UNIVERSITY OF WYOMING

Ruckelshaus Institute
Haub School of ENR
1000 E University Ave, Dept 3971
Laramie, WY 82071

Joe Riis/USFS