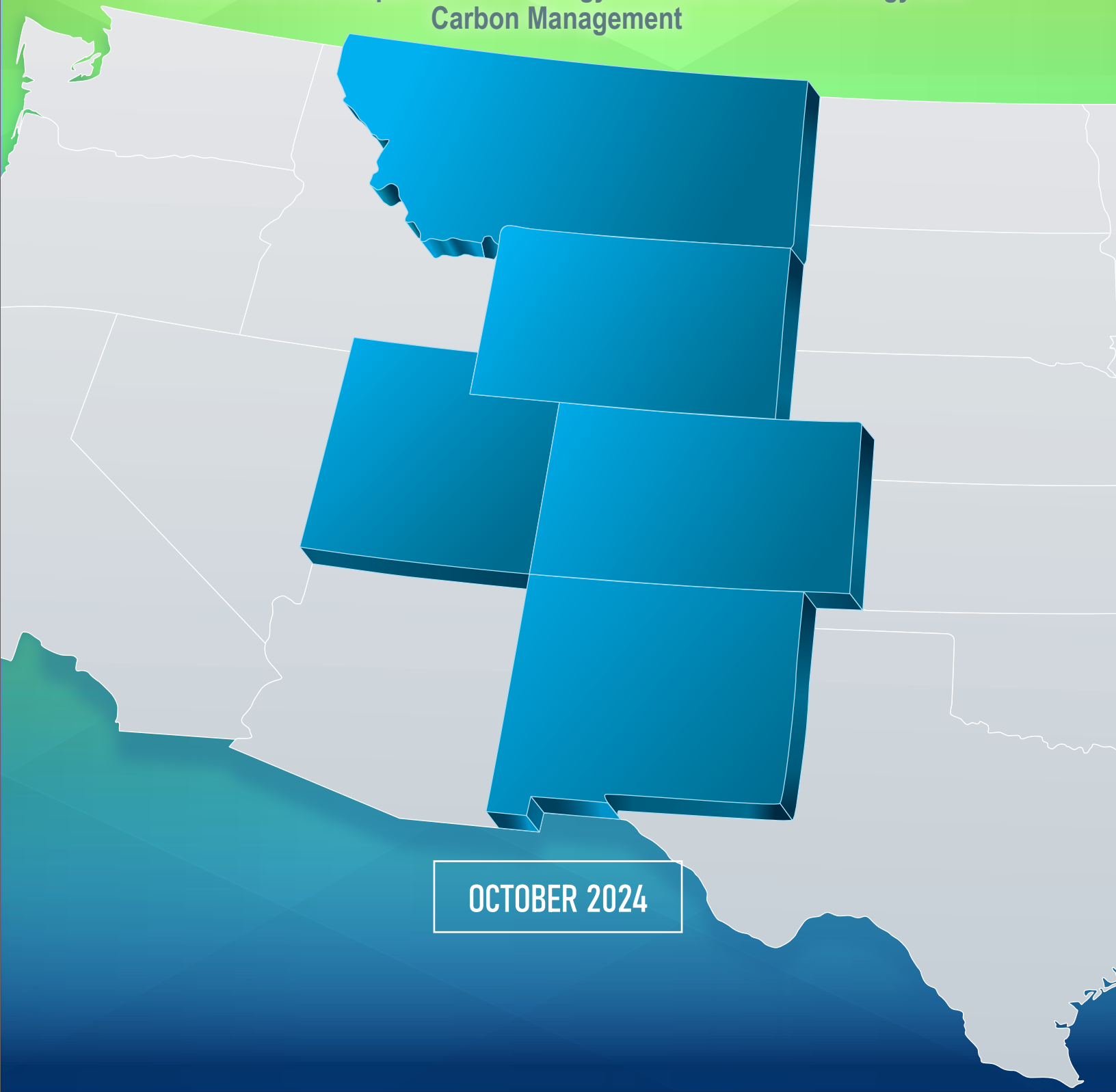
U.S. DEPARTMENT OF ENERGY | Fossil Energy and Carbon Management

MOUNTAIN REGIONAL REPORT

Building a Clean Energy and Industrial Economy and the Supporting Role of the U.S. Department of Energy's Office of Fossil Energy and Carbon Management



OCTOBER 2024

Contents

Purpose of this Report

The "**Mountain Regional Report: Building a Clean Energy Economy and the Supporting Role of the U.S. Department of Energy's Office of Fossil Energy and Carbon Management**" aims to deepen the understanding of the decarbonization opportunities and challenges in the Mountain region, supporting broader efforts to achieve a clean energy and industrial future. The Mountain region, as defined in this report, includes **Colorado, Montana, New Mexico, Utah, and Wyoming**. It draws on the region's energy resources and mining history. Coupled with its geological formations, these resources support current efforts to decarbonize and scale clean energy technologies. Additionally, by referencing the region's industry, energy mix, and energy activities, this report identifies priority areas for the Mountain region and aligns them with the research, development, and demonstration portfolio of the U.S. Department of Energy's (DOE's) Office of Fossil Energy and Carbon Management (FECM) to curate relevant solutions.

This report was developed by the Office of Fossil Energy and Carbon Management in collaboration with the National Energy and Technology Laboratory (NETL).

This report is being disseminated by the Department of Energy. As such, this document was prepared in compliance with Section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554) and information quality guidelines issued by the Department of Energy.

Introduction

The U.S. energy portfolio and economy currently depend heavily on fossil energy. It is crucial to advance clean energy solutions, such as carbon capture and storage, carbon dioxide (CO_2) removal, and other decarbonization pathways, to achieve a net-zero greenhouse gas emissions economy. FECM is dedicated to minimizing the environmental and climate impacts of fossil energy production and use, while working to achieve a clean energy and industrial future. Its portfolio encompasses the research, development, demonstration, and deployment of technologies and infrastructure, including carbon capture, carbon conversion, carbon dioxide removal, carbon dioxide transport and storage, hydrogen production with carbon management, methane emissions reduction, and critical minerals production and processing.

As part of successfully implementing this portfolio, FECM is engaging with communities and stakeholders across the country where significant project development is expected to occur to ensure community and stakeholder participation, understand and address concerns, and increase awareness regarding FECM funding and available opportunities. FECM focuses on two-way engagement, in which communities and stakeholders are not only informed, but they also have the opportunity provide input and shape the design and development of projects and infrastructure that affect them. This aligns with DOE's broader priority of placing stakeholders and local communities at the center of project development efforts, ensuring that DOE's investments result in tangible benefits for communities.

The Community Benefits Plan framework is one example of a significant initiative that aims to institutionalize this priority. This framework aims to ensure that projects receiving public funding, particularly from the Bipartisan Infrastructure Law and the Inflation Reduction Act, create economic, environmental, and societal benefits for the communities and workers where projects are located. Through close collaboration between developers and communities, Community Benefits Plans can evolve into Community Benefit Agreements, which are legally binding agreements between community groups and developers, stipulating the benefits a developer agrees to fund or furnish in exchange for community support of a project. DOE does not require Community Benefit Agreements but encourages them as an outcome of developing a Community Benefits Plan. Ideally, strong Community Benefits Plans result in formal agreements to create lasting benefits that will continue after DOE's involvement in a project ends.

As outlined throughout this report, FECM's focus areas and portfolio of technologies are well-aligned with the Mountain region's energy mix, local infrastructure, and resources. These efforts will also help the region engage communities, create new jobs, build new supply chains and industry, and invest in supporting private sector and university research and development and innovation. Further, through DOE's Community Benefits Plans, FECM illustrates how the design and scope of a project can maximize economic, environmental, and societal benefits for communities in the region, contributing to project success.

Mountain Region – Strategically Located and Net Exporter of Oil, Gas, Coal, Electricity, and Metals

The Mountain region accounts for 21% of oil production, 15% of gas production, and 52% of U.S. coal production.[1] The coal produced in this region is primarily low sulfur, sub-bituminous coal from Wyoming, which contains the lowest sulfur content in the United States, with carbon content and heating values lower than bituminous coal but higher than lignite coal. In the region, 83% of crude oil production and 76% of natural gas production come from New Mexico and Colorado, with crude oil primarily deriving from the Permian[2] and Niobrara Shale formations; natural gas from the Permian, Denver-Julesburg (DJ), Green River, and Piceance basins; and coalbed methane gas (natural gas extracted from coal seams) from the San Juan and Raton basins. Although Utah's natural gas production has declined over time, it has a large underground natural gas storage reservoir and three natural gas storage facilities with a combined storage capacity of almost 125 billion cubic feet, equal to about 1% of the nation's total natural gas storage capacity.[3]

The region is a net exporter of oil, gas, coal, electricity, and metals, and well-connected to U.S. infrastructure with crude, product, and natural gas pipelines, railroads, and transmission interconnections. Coal is shipped from this region via railroad to multiple markets in the United States and to ports to be shipped abroad. Four out of five states in the region (MT, NM, UT, WY) are net exporters of electricity. Energy-intensive industry has developed in close proximity to the energy resources in the region. Of the total energy consumption, 32% is used in industrial processes, which includes mining and oil and gas production. There are 45 energy-intensive facilities in the region across refining, ammonia, lime, cement, glass, soda ash, and bioethanol.[4] Products from these facilities are shipped to multiple markets across the United States. For example, there are 16 refineries in the region, with Utah, Wyoming, and Montana importing crude and exporting refined products to Colorado and multiple markets outside the region.

As described in the USGS mineral industry state profiles, the mining industry is one of the most important industries in the region, not only because of the GDP contribution and associated jobs, but also because of the critical minerals and materials produced for the U.S.[5] The Mountain region can play an important role in U.S. ambitions to develop domestic critical minerals and materials supply chains. There are 40 coal mines in the region: 12 are underground mines, where the coal is more than 200 feet below the surface, requiring tunnels and mine shafts; and 28 are surface mines, where coal is less than 200 feet underground and large machines are used to remove the topsoil and layers of rock.[6] In addition, the region has a high concentration of hard rock

[1] EIA

[2] The Permian basin is primary in Texas but extends to Southeastern New Mexico.

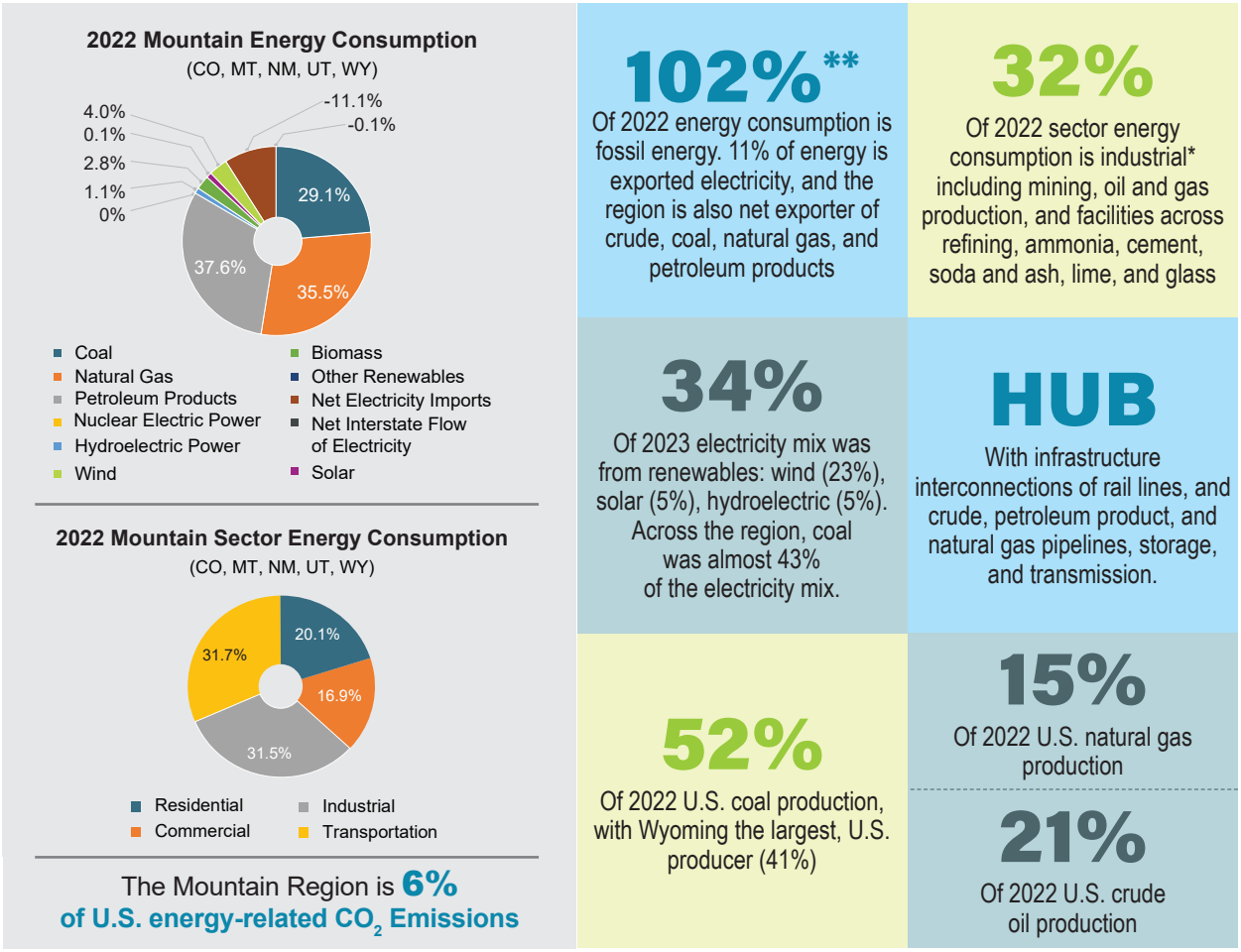
[3] EIA

[4] EPA Flight database EPA Facility Level GHG Emissions Data

[5] The Mineral Industry of Colorado | U.S. Geological Survey; The Mineral Industry of New Mexico | U.S. Geological Survey; The Mineral Industry of Utah | U.S. Geological Survey; The Mineral Industry of Wyoming | U.S. Geological Survey; The Mineral Industry of Montana | U.S. Geological Survey

[6] EIA

Figure 1: Energy in the Mountain Region



Source: EIA. Energy consumption (also referred to as energy mix) includes fuels consumed and electricity exported (negative net interstate flow). Electricity mix includes electricity generated from fossil, nuclear, and renewable plants. See EIA glossary. Glossary - U.S. Energy Information Administration (EIA)

* Industrial includes manufacturing and non-manufacturing (e.g., mining, agriculture, oil & gas) industrial sectors

** Total fossil energy consumption is the sum of the coal + natural gas + petroleum products consumed in the states in the region, including what is used to generate electricity. Exported electricity (generated from fossil and renewables) is represented as negative consumption (e.g. -11.1%). If the share of electricity exported is greater than the share of electricity generated from renewables, the fossil energy consumption will be greater than 100%.

mines across many minerals, including uranium. In fact, there are uranium reserves in all five states and the U.S.' only operating uranium ore mill is in Utah.

Although coal-fired generation comprises 43% of the region's electricity mix, all the states have programs and/or plans to increase renewable electricity and reduce industrial and power sector emissions with carbon management. Some of the states in this region have even published plans on the future of energy in their states such as the "Colorado Greenhouse Gas Pollution Roadmap 2.0[7]," the "Wyoming Energy Strategy[8]," and "Utah's Energy and Innovation Plan[9]."

[7] GHG Pollution Reduction Roadmap 2.0 | Colorado Energy Office

[8] Strategy - Wyoming Energy Authority (wyoenergy.org)

[9] Utah Energy and Innovation Plan - Office of Energy Development

Colorado's Greenhouse Gas Pollution Reduction Roadmap 2.0 outlines near-term actions to reduce emissions to meet Colorado's target of a 50% reduction in pollution by 2030. Colorado's plan includes aggressive growth in renewables and electrification of transportation, reducing emissions from the oil and gas industry and from coal mines, expanding funding for industrial decarbonization, establishing statewide regulations for carbon management, and enabling a clean hydrogen economy.

A key commitment of Utah's Energy and Innovation Plan is to advance an "any of the above" energy future to support domestic energy development, pragmatic market-driven climate solutions, and economic development in rural communities. Utah's energy mix includes increasing amounts of solar, wind, hydrothermal, and geothermal technologies; as well as an intention to expand to other technologies including battery storage, hydrogen, nuclear, and carbon capture. Another key commitment is to support "an environmentally responsible energy future through a strong and sensible mining program for critical minerals."

The tagline for Wyoming's Energy Strategy is "Empowering our nation with an all-of-the-above energy mix." The project portfolio in Wyoming's "All-of-the-Above Strategy" includes harnessing the Wyoming Integrated Test Center to allow researchers to test carbon capture technologies using actual coal-based flue gas, participating in DOE's Carbon Storage Assurance Facility Enterprise (CarbonSAFE) initiative to assess storage complex feasibility, establishing geologic storage as a service (and source of economic activity, employment and revenue), and producing and exporting hydrogen.

Montana's electricity mix is over 48% renewable with policies to support further growth in wind, solar, geothermal, and biomass. Electricity – and growing renewables – continues to be a big focus because of the interconnections with the western states and the opportunity to export low-carbon electricity. However, Montana has a long history of coal production, with almost 45% of electricity generated from coal; and incentivizes carbon capture through mandating 50% carbon capture requirements for new coal plants and property tax abatements for carbon capture equipment[10].

New Mexico generated more electricity from wind in 2023 than any another source, generating almost 46% of electricity from renewable sources. In 2019, New Mexico signed into law the Energy Transition Act (ETA) that set a statewide renewable energy standard of 50% by 2030 for New Mexico-based investor-owned utilities and rural electric cooperatives. It is the only state in the region where electricity from natural gas (35%) is greater than electricity from coal (19%). However, electricity, as in all markets, accounts for only a portion of the energy consumed. Despite the share of renewable electricity, New Mexico's primary energy consumption is 100% fossil energy because a significant amount of energy is exported as electricity (almost 13%)[11] and transportation and industry, including oil and gas, aerospace and defense, and agriculture, account for 70% of the state's energy consumption and are difficult to electrify As the second largest oil producer in the United States, reducing methane emissions and managing produced water from oil and gas operations are also state priorities.

The portfolio of technologies being developed by FECM and other offices across DOE are well-suited to support the Mountain region's efforts to increase the share of clean energy technologies and to decarbonize existing energy and industrial production. These efforts are further supported by the Bipartisan Infrastructure Law

[10] Understanding Energy in Montana 2023 (mt.gov); Montana - Carbon Capture Ready (betterenergy.org)

[11] Fossil energy consumption is all uses of coal+natural gas + petroleum products. Some of these fossil fuels are used to generate electricity. Some of that electricity is exported. Exported electricity will have been generated from both fossil and renewable sources.

and the Inflation Reduction Act, which are helping to enable a robust market for clean energy and industrial projects through a comprehensive portfolio of funding, financing, and tax incentives.

As a part of the Bipartisan Infrastructure Law, DOE will deploy approximately $12 billion in new carbon management funding over five years, including $2.5 billion for six large commercial-scale carbon capture demonstrations and approximately $1.0 billion for large-scale pilot projects under the office of Office of Clean Energy Demonstrations; $2.1 billion for CO_2 transportation infrastructure; $2.5 billion for developing large-scale regional geologic storage sites; and $3.5 billion for regional direct air capture hubs. As part of the $2.1 billion in funding for CO_2 transport, FECM is working with the Loan Programs Office (LPO) to offer access to capital for large-capacity, common-carrier CO_2 transport projects (e.g., pipelines, rail, shipping, and other transport methods). Additionally, FECM is offering "Future Growth Grants" as part of the Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA) program to extend or enlarge planned carbon transport infrastructure to connect additional CO_2 sources.

The federal 45Q tax credit provides up to $85 per metric ton of CO_2 captured from industry and power generation for dedicated storage in geologic formations; $60 per metric ton of CO_2 captured and geologically stored through the process of enhanced oil recovery; $60 per metric ton of CO_2 captured and converted into low carbon products or utilized (subject to the life cycle analysis and CO_2 emissions reductions); and up to $180 per metric ton for direct air capture facilities with dedicated storage in geologic formations. Enhancements to the tax credit include: a ten-year extension of the eligibility date (i.e., all projects beginning construction by the end of 2032 are eligible); the ability to claim the credit for 12 years of operation, directly as a cash payment for the first five years of operation, and the option to transfer the credit to outside investors for the remaining seven years; and expanded eligibility for smaller industrial, power generation, and direct air capture facilities.

Since the Bipartisan Infrastructure Law and the Inflation Reduction Act, the number of U.S. carbon management projects announced annually by the private sector has more than doubled since 2019. Of the 219 cumulative projects in the Clean Air Task Force database, 20 are in the Mountain region[12]. In 2023 alone, over $6.5 billion was invested in carbon management in the U.S., with 4% of this investment in the Mountain region[13]. The application queue for geologic storage permits under U.S. Environmental Protection Agency's (EPA) Class VI Underground Injection Control Program is another indicator of activity, with 148 well applications under review by the EPA across the U.S., including applications in Colorado and New Mexico[14]. In the Mountain region specifically, EPA has granted Class VI primacy to Wyoming, giving the state's regulators delegated authority to permit geologic storage projects directly.

There are a wide range of other tax credits as well. The 45X tax credit provides a 10% credit to produce 50 different critical minerals that are essential to our clean energy economy and national security. The 45V tax credit creates a new 10-year incentive for clean hydrogen production of up to $3.00/kilogram. The level of the 45V credit provided is based on carbon intensity (i.e., the lower the carbon intensity, the higher the credit), with a maximum of four kilograms of CO_2-equivalent per kilogram of clean hydrogen eligible for the tax credit.

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[12] CRES illustration with data from IEA, https://www.iea.org/data-and-statistics/data-product/ccus-projectsdatabase. Used in GPI presentation at 2024 NETL Annual Review meeting; U.S. Carbon Capture Project Map – Clean Air Task Force (catf.us) August 28, 2024

[13] https://www.cleaninvestmentmonitor.org/database as of August 28th, 2024

[14] U.S. EPA Class VI Permit Tracker as of August 30, 2024. (Current Class VI Projects under Review at EPA | US EPA)

Industry

Industrial and energy facilities and mining sites are already well-connected by pipelines and rail, providing an opportunity for carbon management in this region.

There are about 45 energy-intensive facilities in the region across refining, ammonia, cement, soda ash, lime, and glass. Carbon capture will be important to these facilities, as most have industrial processes that cannot be electrified or decarbonized more economically through other low-carbon methods, or that generate CO_2 as a byproduct of the industrial process itself, rather than through combustion of fuels. Many of these facilities have decades of useful life remaining, and it would not be economically feasible to retire them early. The DOE is supporting industrial carbon capture projects in the region. For example, in Colorado, FECM is funding the pre-feasibility study using thermal swing adsorption technology to capture CO_2 at commercial scale from a cement plant. There are also an additional further 75 natural gas processing plants in the region that already separate CO_2 and could readily deploy capture at low cost with the development of CO_2 transport and storage hub infrastructure that could be shared with other industrial facilities to achieve economies of scale.

In the power sector, electricity produced from coal accounted for almost 43% of the region's 2023 electricity mix (with generation amounting to 45% in Montana, 47% in Utah, and 71% in Wyoming). Some DOE- funded projects in the region have evaluated technologies for CO_2 capture at coal-fired power stations, with pilot-scale testing and demonstrations being conducted at the Wyoming Integrated Test Center, such as the FECM-funded large pilot testing of a membrane post-combustion CO_2 capture process. The DOE is also funding a large-scale carbon capture pilot at the Dry Fork Power coal-fired station through the Carbon Capture Large-Scale Pilot Projects Program. The transport and storage infrastructure needed for the captured CO_2 from coal-fired power plants could be shared by industrial facilities in the region, and CO_2 transport routing could leverage existing rail lines and rights of way that are already shipping coal to industrial and power facilities.

Additionally, carbon management technologies can also support the continued growth of variable wind and solar electricity in the region, which already accounted for almost 34% of the electricity mix in 2023. The region exports renewable electricity and is part of the Western Interconnection giving the region access to California and its increasing demand for low carbon electricity. Natural gas power plants have played a key role in enabling wind and solar[15] penetrations in Colorado and New Mexico to reach 34% and 45% in 2023, respectively, by providing flexible output. Electricity from natural gas increases when wind and solar generation is low and decreases when wind and solar generation is high, capturing the CO_2 emissions associated with natural gas power plants will require carbon capture and storage technologies to be compatible with this flexible operation. DOE is investing in such technologies through the Advanced Research Projects Agency- Energy's (ARPA-E) FLExible Carbon Capture and Storage program (FLECCS). Researchers at Colorado State University

[15] Only includes utility-scale solar. Small scale solar is excluded as per EIA electricity total fuels scope definition. Small scale would only increase solar penetration by 0.8-2%

and its partners—ION Clean Energy, Worcester Polytechnic Institute, and Bright Generation Holdings—will develop a thermal energy storage system with flexible advanced solvent carbon capture technology. The system aims to decrease the levelized cost of electricity for natural gas-fired combined cycle (NGCC) power plants to <75 $/MWh while simultaneously capturing >95% of CO_2 emissions when operating in markets with high penetrations of variable renewable electricity.

Projects intending to remove CO_2 from the atmosphere and durably store it using carbon dioxide removal technologies are also growing in number and size in the region. DOE funds research in carbon dioxide removal at the National Renewable Energy Laboratory in Colorado and Sandia and Los Alamos National Laboratories in New Mexico. Two projects awarded under the Bipartisan Infrastructure Law-funded Regional Direct Air Capture Hubs program will study the feasibility of deploying direct air capture hubs in both Pueblo, Colorado and Southwest Utah. FECM's Carbon Dioxide Removal Purchase Pilot Prize has awarded funds for direct air capture projects expected to be deployed in Colorado and a terrestrial biomass storage project expected to be deployed in Montana. There are also several non-DOE funded carbon dioxide removal activities advancing in the region, including Zero Carbon Systems, which acquired Global Thermostat and its 1,000-ton-per-year direct air capture pilot plant in Colorado; the 4 Corners Carbon Coalition's awards to biomass carbon removal and storage projects across New Mexico, Colorado, and Utah; and Spiritus's announced direct air capture project in Wyoming.

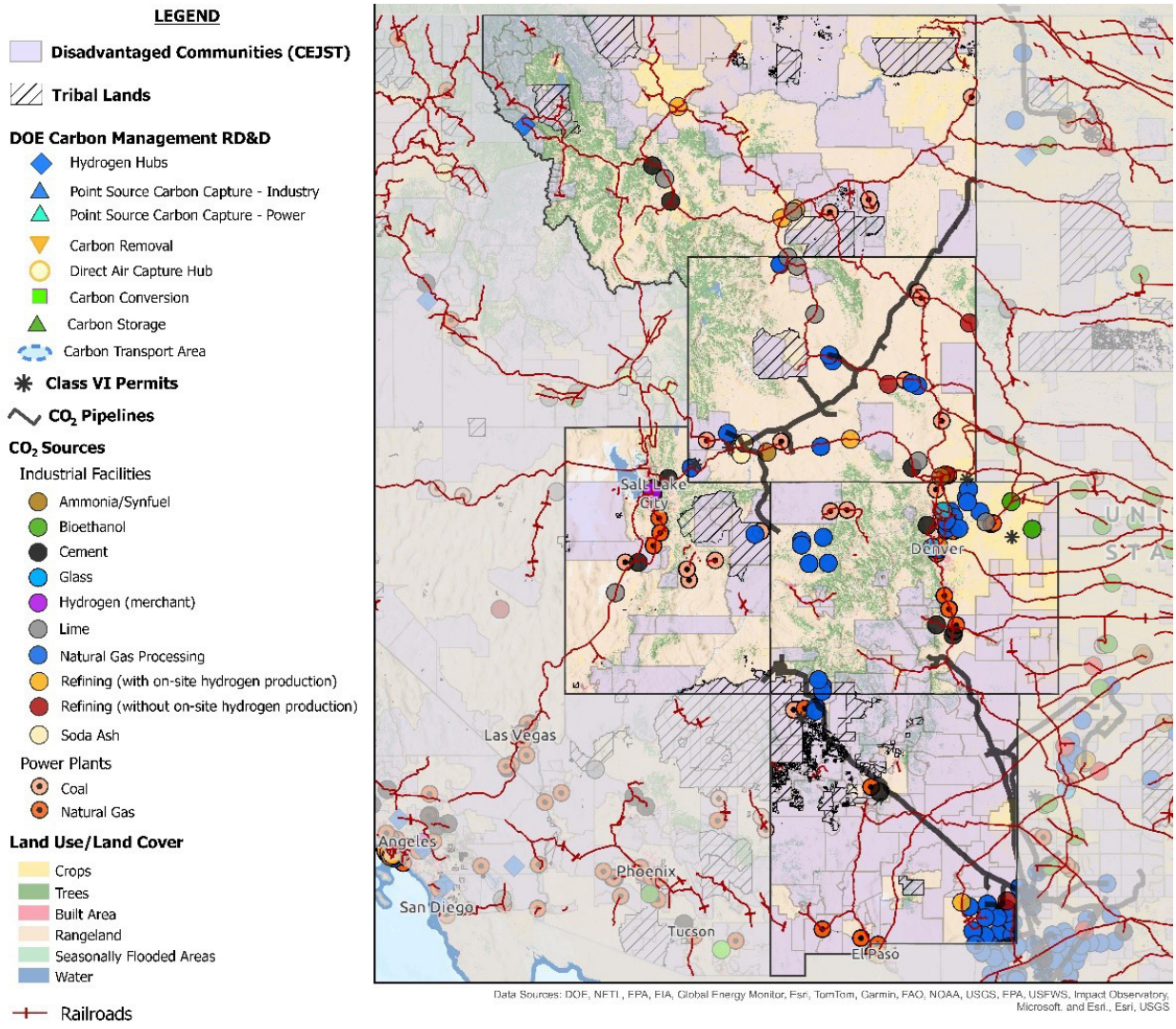
The region's "all of the above" approach is also apparent in the different hydrogen production activities. FECM's financial assistance for hydrogen with carbon management in the region has historically focused on gasification of coal, biomass, and waste to produce hydrogen, along with development of air separation technologies to reduce the cost of oxygen for oxygen-blown entrained flow gasification. DOE has also provided financial assistance to several gasification projects at the University of Utah. However, hydrogen activity in the region also includes developing real-time, efficient, and economical characterization and monitoring methods for measuring processes that produce geologic hydrogen in Colorado through a project receiving financial assistance from ARPA-E; a large project to explore renewable hydrogen production in Utah funded by DOE's Loan Program Office (LPO), which aims to produce hydrogen from solar, store it underground, and then generate power (although initially the power plants will be generating the electricity from natural gas with hydrogen blended in); and Wyoming's state-funded coal-to-hydrogen with carbon capture projects.

Large-scale regional projects can create an ecosystem of regional CO_2 transport and storage coupled to carbon capture across a wide range of industries, power generation, carbon conversion, and direct air capture. Although there can be added complexities to linking up multiple sources and aligning the timing of multiple project stages and agreements on various aspects of the transport and storage infrastructure, such shared infrastructure could reduce costs and accelerate project deployment and emissions reductions. A recent paper from Princeton University found that when CO_2 pipelines are shared, rather than dedicated to individual capture facilities, average transport costs can be reduced by two-thirds.[16] As shown in Map 1, the Mountain region already has experience with CO_2 pipelines that currently send CO_2 from the McElmo and Sheep Mountain CO_2 domes in Colorado to West Texas for enhanced oil recovery. Additionally, there is an opportunity to leverage the exiting rail lines and rights of way that already connect multiple facilities.

[16] Shared CO_2 capture, transport, and storage for decarbonizing industrial clusters - ScienceDirect

Map 1: Industrial Activity in the Mountain Region

Facilities across the region can share carbon management infrastructure, creating the opportunity to reduce emissions from the region's industrial production and power generation and from its energy and electricity exports.



Source: National Energy and Technology Lab (NETL) Research & Innovation Center (RIC). Developed using publicly available data sources (EPA, USGS, etc.).

DOE is investing in bold industrial decarbonization technologies at each stage of the innovation pipeline to help industry use clean energy, increase efficiency, and integrate new, innovative processes and technologies. These technologies will support decarbonizing the Mountain region while also protecting and creating high-wage industry jobs. This will enable industry to establish additional pathways to decarbonize existing infrastructure in the near-term.

The carbon management infrastructure necessary to realize the decarbonization opportunities in this region has the potential to benefit landowners, including ranchers and farmers, and local and tribal communities, through direct compensation and by bringing local economic development, jobs, and reskilling opportunities. To realize the full potential of these opportunities in the Mountain region, and for project success, it is critically important that there is early and ongoing two-way engagement between developers and impacted stakeholders regarding how project design and scope can maximize economic and societal benefits for host communities and mitigate environmental risks. Developers also need to address concerns such as pipeline safety (particularly in small towns that rely on volunteer fire departments) and the long-term impacts to the productivity and value of farm and ranch lands. Developers whose projects proceed with or without federal funding can refer to FECM's "Responsible Carbon Management Initiative" as a guide for how to pursue the highest levels of safety, environmental stewardship, transparency, and community engagement and benefits in project development.

Energy and Resources

The Mountain region is working to reduce the emissions from fossil energy production and export, has significant geological storage potential, and is well-positioned to expand its energy trade to include CO_2 transport and storage.

The Mountain region has a long history of coal, oil, and natural gas production and use. There has been a focus on improving the environmental footprint of these operations and reducing emissions. The sub-bituminous coal produced in Wyoming is already the lowest sulfur coal in the United States. Colorado, Utah, and New Mexico's energy plans feature reducing emissions from oil and gas activities. FECM's Methane Mitigation and Advanced Remediation Technology divisions support these efforts, as does the FECM-Environmental Protection Agency (EPA) Methane Emissions Reduction Program (MERP).

FECM's Methane Mitigation Technologies Program focuses on achieving near-elimination of methane emissions from the oil and gas supply chain by 2030—from production to processing, transportation, storage, and end-use. In March, the Program invested nearly $20 million in funding for Colorado State University to accelerate the development, validation, and deployment of next-generation leak detection and quantification technology solutions at its Methane Emissions Technology Evaluation Center (METEC). The five-year METEC project extends the capability of DOE-funded assets and supports value-added research capabilities, including:

- Modernizing the testing facility to more closely mimic current upstream oil and natural gas facilities responsible for fuel extraction and production.
- Continuing to facilitate the development and pre-commercial demonstration of leak detection and quantification solutions.
- Reducing uncertainty and risk for leak detection and quantification solutions through advanced modeling and artificial intelligence.
- Extending the capability of testing leak detection and quantification solutions for hydrogen and hydrogen/natural gas blends.

FECM also selected four research and development projects to receive nearly $32 million to advance technologies that will help reduce natural gas flaring at oil production sites, a significant source of greenhouse gas emissions, by transforming gas into valuable products that would otherwise be wasted. One of the four projects is in Colorado and will field test the emission control treater—a new well pad processing technology that replaces existing equipment while eliminating nearly all methane emissions sources on the pad—at a well site in the Denver-Julesburg Basin of Colorado.

The Advanced Remediation Technologies program area is another resource for this region as the treatment and beneficial reuse of produced water is a priority. A significant amount of water is used and produced in onshore oil and gas operations. Produced water is a term used in the oil and gas industry to refer to the water that comes

out of a well during the oil and gas production process. In parts of the region (e.g., New Mexico), access to water for agriculture and industry is an increasing consideration, making responsible water management and treatment of produced water increasingly important for operators in the region.

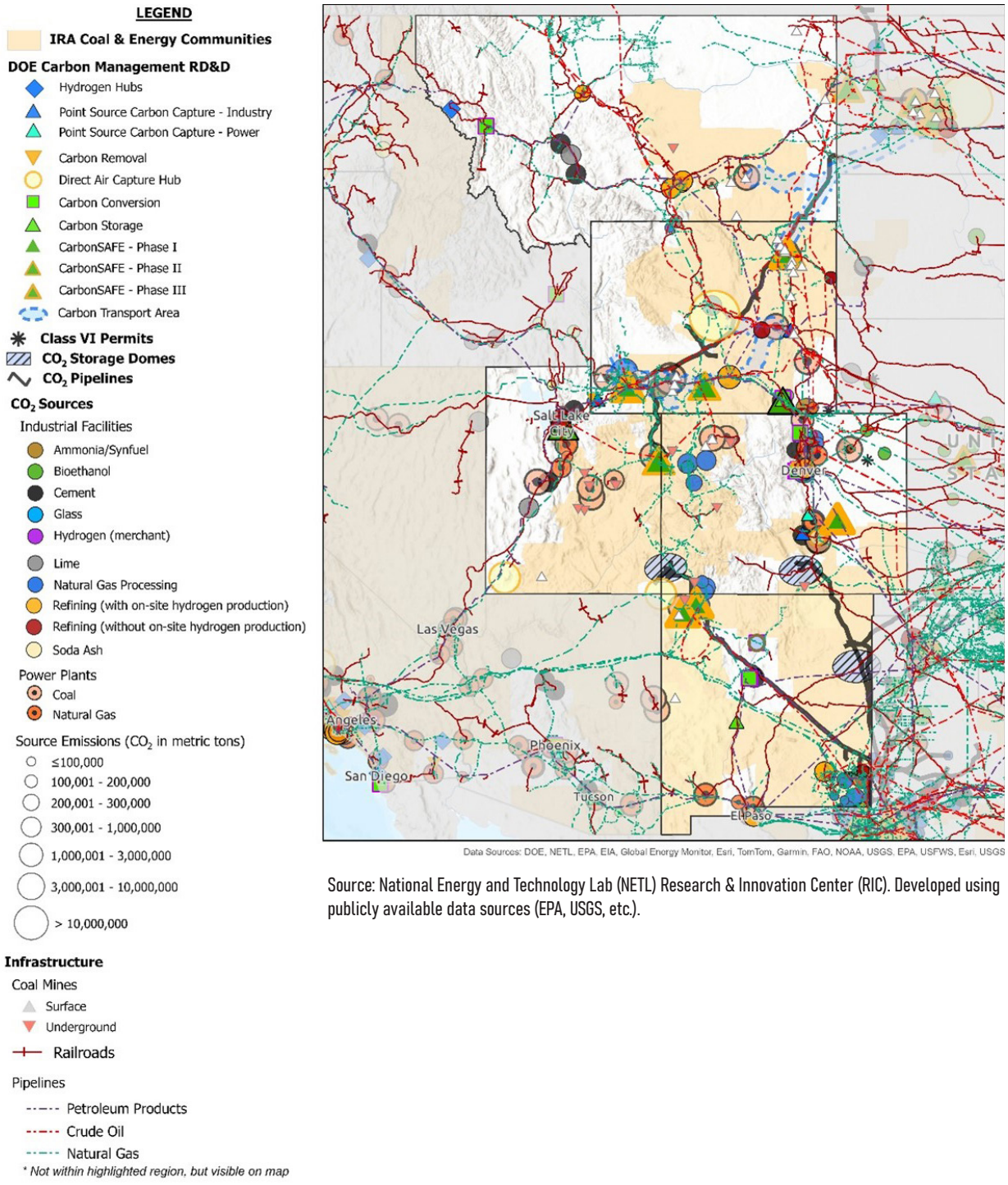
In addition to these ongoing efforts, FECM and NETL are working with EPA to implement $1.36 billion in technical and financial assistance through the Methane Emissions Reduction Program that was established under the Inflation Reduction Act to target methane emissions across the oil and natural gas supply chain. The program will provide funding to undertake a wide range of measures, including monitoring methane emissions; voluntarily plugging high-emitting, low-producing marginal wells and reducing emissions at other operating wells and infrastructure; and providing financial assistance for installing technology to reduce emissions from equipment such as valves, tanks, and compressors. In December 2023, the Biden-Harris Administration announced an award of $350 million to 14 states, including Colorado, Utah, and New Mexico, in the amounts of $12.9 million, $2.8 million, and $14.7 million, respectively, to reduce methane emissions from the oil and gas sector. In June 2024, DOE and EPA made a joint announcement that up to $850 million in federal grant funding will be made available competitively to industry, research and technical organizations, tribes, communities, and others for projects that monitor, measure, quantify, and reduce oil and gas sector methane emissions.

The region's efforts to reduce emissions from oil and gas activity will support the region's future competitiveness as its export markets and buyers increasingly consider emissions and the environmental impact of natural gas, petroleum products, and electricity from the region. In addition to the Mountain region's current role as energy and electricity exporter, as shown on Map 2, there is also an opportunity to provide CO_2 storage services for neighboring markets. The region's geology offers the potential to store CO_2 from power plants and industrial facilities, as well as CO_2 removed from the atmosphere via direct air capture. Managing CO_2 resources is not new to the Mountain region. As shown in Map 2, the Mountain region has existing CO_2 pipelines that send CO_2 from the McElmo and Sheep Mountain CO_2 domes in Colorado to West Texas for enhanced oil recovery. CO_2 domes are underground formations where naturally occurring CO_2 has been contained for more than a million years. In 2022, the McElmo and Sheep Mountain CO_2 domes produced 3.9 and 0.4 million metric tons of CO_2, respectively[17]. As a result of this production and export, there is existing infrastructure in place to possibly transport and store captured CO_2 emissions in these domes and provide an early foundation for future CO_2 transport and storage hub development.

[17] https://www.epa.gov/ghgreporting/supply-underground-injection-and-geologic-sequestration-carbon-dioxide; GHG Summary Report (epa.gov)

Map 2: Energy Infrastructure and Resources in the Central Mountain Region

Significant geologic potential and an experienced workforce can make this a competitive region for storage of CO_2 emissions from industry and power generation from within and from outside the region ($/metric ton of CO_2 abated).



Source: National Energy and Technology Lab (NETL) Research & Innovation Center (RIC). Developed using publicly available data sources (EPA, USGS, etc.).

In 2003, DOE embarked on a series of regional carbon storage research and development projects. These efforts included the initial characterization of CO_2 sources and storage opportunities on a regional basis, and injection of CO_2 into a wide variety of geologic storage formations to test capacity, injectivity, containment, and storage operation

protocols. Building on these efforts, in 2016, the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) program was launched to support the commercial development of geologic storage and provide crucial resources and information necessary for large-scale geologic storage facilities or carbon management hubs. As shown on Map 2, there are a number of Phase II and Phase III DOE-funded CarbonSAFE projects in the region. For example, San Juan Basin CarbonSAFE Phase III will perform a comprehensive commercial-scale site characterization of a storage complex located in northwest New Mexico. The data collected by the characterization and environmental analysis will be used to prepare, submit, and attain an EPA Underground Injection Control Program Class VI permit (for construction) to inject and store a minimum of 50 million metric tons of CO_2 at the site. Another project, the Wyoming CarbonSAFE: Accelerating Carbon Capture Utilization and Storage Commercialization and Deployment at Dry Fork Power Station and the Wyoming Integrated Test Center, builds on previous phases and will finalize surface and subsurface site characterization and certify the safety and security of eventual commercial carbon capture, utilization, and storage operations at the power station. The Uinta Basin CarbonSAFE II Study intends to establish the feasibility of commercial CO_2 storage in Utah's Uinta basin to combine additional CO_2 sources in the area for storage hub development. Finally, in Southern Colorado, the CarbonSAFE Eos project plans to develop a regional geologic CO_2 storage hub to manage emissions from diverse sources, including cement, hydrogen and power.

The national network of CarbonSAFE projects is on track for targeted commercial injectivity of 100 million metric tons per year and to identify contingent storage resources[18] of 6 billion metric tons by 2035. In addition to geologic resource characterization, modeling, permitting and, ultimately, construction and commercial operations, the projects incorporate public engagement and provide technical assistance and resources to communities. As described earlier, the Bipartisan Infrastructure Law provisions for financing geologic storage and CO_2 transport provide crucial support for the development of these storage opportunities.

As shown on Map 2, there are a significant number of communities in this region with a long history of experience living and working alongside the energy and mining industries. This skilled energy and mining workforce makes the Mountain region suitable for deployment of geologic storage, creating opportunities for high-wage jobs. The Rhodium Group and Great Plains Institute estimate that carbon capture and storage could create 17,160 annual jobs across Montana, Colorado, Wyoming, Utah, and New Mexico[19], helping to ensure the Mountain region benefits from the development and operation of the carbon management technologies and infrastructure. Many of the states in the region are investing in workforce development and are participating in FECM's University Training and Research program, which aims to educate and train the next generation of engineers and scientists. For example, two projects at New Mexico Institute of Mining and Technology aim to develop and sustain visiting scholar programs in which students from several minority-serving institutions will be trained in research related to carbon capture, utilization, and storage and direct air capture, preparing underrepresented students for jobs in clean energy technologies. Another project at the University of Utah explores new energy and economic transition pathways for a coal community, particularly through recovering critical minerals from coal and constructing utility-scale solar power plants.

[18] Contingent storage resources are storage resources estimated to be accessible in known geologic formations, but the applied project(s) are not yet considered mature enough for commercial development, as a result of one or more contingencies. srms_sep2022_w_errata.pdf (spe.org)

[19] Carbon Capture and Storage Workforce Development: State-by-State | Rhodium Group (rhg.com)

Recovery of Critical Minerals

With the Mountain region's history of mining coal and a wide range of minerals, there is an opportunity to develop domestic critical minerals supply chains in the region.

The Mountain region is well-positioned to have a key role in developing a domestic source of critical minerals and materials. Critical minerals, including rare earth elements, are key to manufacturing clean energy and industrial technologies—such as solar panels, wind turbines, electric vehicles, and hydrogen fuel cells—that will help the United States achieve a net-zero emissions economy. They are also essential to the manufacture of technologies and products vital to our country's national security. Demand for critical minerals and materials is growing in the United States and globally, and the United States vulnerability is likely to grow. For example, the U.S. currently imports greater than 80 percent of its rare earth elements from non-domestic suppliers. All five states in the region have significant critical mineral resources and are active in the U.S. Geological Survey (USGS) Earth Mapping Resources Initiative[20] (Earth MRI) to modernize the surface and subsurface geologic evaluation across the United States and identify areas that may have the potential to contain critical mineral resources. For example, Utah hosts or has potential for 28 critical minerals, and primary metals make up more than half the total value of Utah's merchandise exports, nearly $9.2 billion in 2020[21]. Large deposits of lithium and rare earth elements have been found in Wyoming. As shown in Map 3, there are currently hundreds of non-coal hard rock mines in the region.

DOE does not have a permitting role in mining, but the Department recognizes that mining new critical minerals will be necessary to meet future national security, clean energy, and advanced technology needs of the country. To that end, FECM's new Mine of the Future Program will invest in research, development and demonstration to advance novel technologies that will revolutionize mining in a way that significantly reduces the environmental and emissions impacts and the safety and cost of mining. These technologies include: advances in geophysics, drilling, artificial intelligence, /machine learning, robotics and automated systems, in-situ extraction and processing technologies, improved tailings management, and material traceability. The goal of this program is to bring a "precision extraction" approach to mining that significantly reduces the ratio of waste-to-mineral brought out of the ground, the amount of water used, the energy needed, the associated greenhouse gas emissions, and the overall emissions to land, water, and air., This program should help minimize impacts and maximize benefits of mining for surrounding communities and regions. This should, in turn, increase public and policymaker acceptance of domestic mining over time, contributing to reduced permitting times and increasing the likelihood of project approvals and financing.

[20] Earth Mapping Resources Initiative (Earth MRI) | U.S. Geological Survey (usgs.gov)

[21] Utah Energy and Innovation Plan - Office of Energy Development

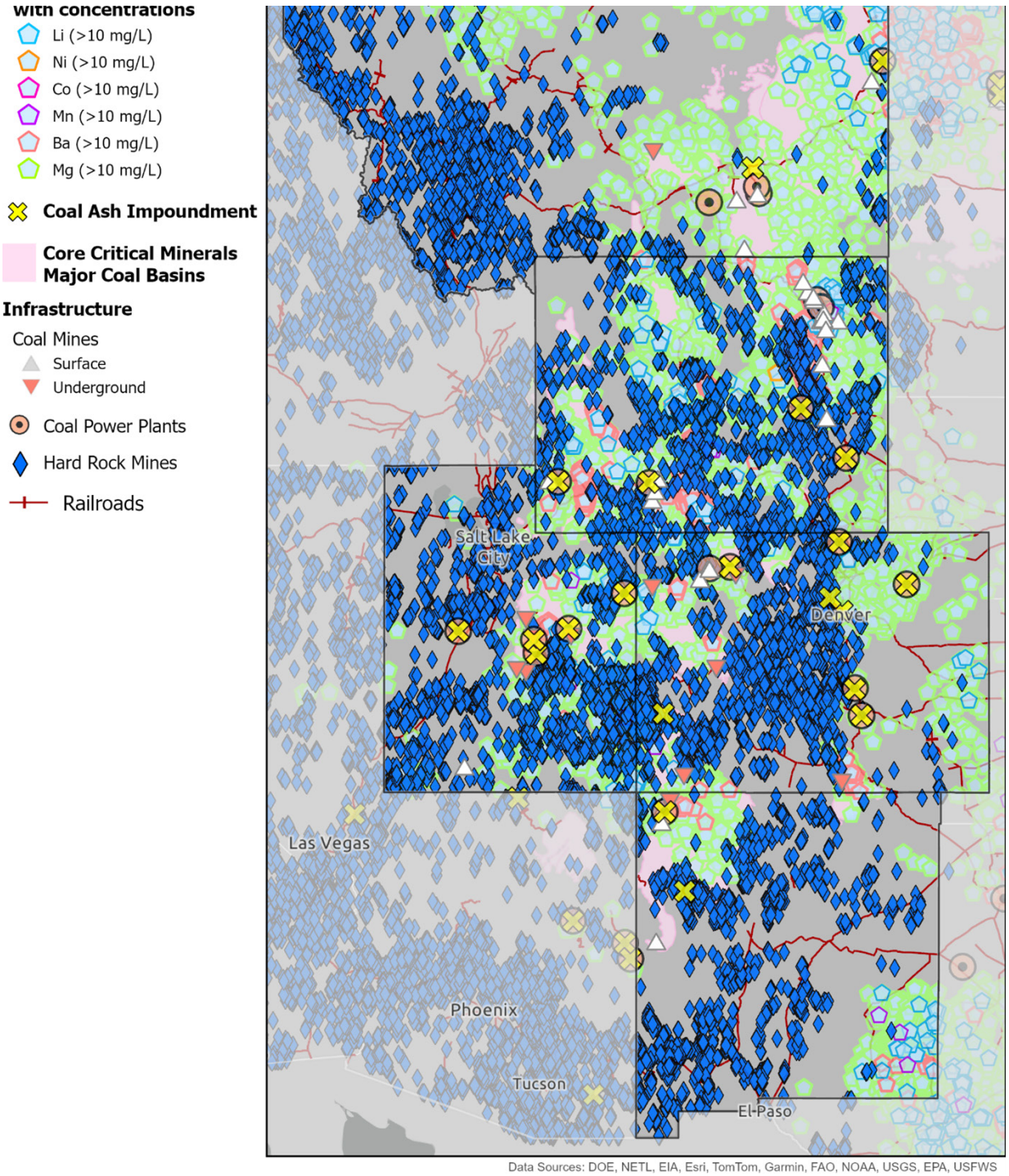
Additionally, rare earth elements and other critical minerals can be found in the coal that is currently being mined in the region. The region's substantial coal mining and usage has resulted in many coal waste piles and ash impoundments. As part of the wider all-of-government effort to increase the domestic mining and production of critical minerals, FECM is pursuing research to recover rare earth elements and other critical minerals from coal, coal-related wastes, and other (hard rock) mining waste streams to develop a domestic supply chain of critical minerals and materials that will reduce U.S. dependence on foreign sources. Even though these distributed secondary and unconventional resources may have relatively low concentrations of rare earth elements and critical minerals, leveraging previously mined materials presents an opportunity to meet our nation's growing demand for these minerals while remediating these legacy wastes, including the acid mine drainage coming from coal and hard rock mining. Furthermore, as coal and hard rock mining continues, there are opportunities to recover and process other critical material byproducts that were previously discarded as waste before they reach a tailings pile. For example, cobalt, nickel, zinc, lithium, and rare earth elements can be present in copper ore material.

Produced waters from the oil and gas fields in the region also contain lithium and other critical minerals. Turning by-products into co-products has the potential to improve the economics of all these resource recovery activities while reducing waste.

Together, the abundance of primary and secondary critical minerals from current and past mining activity, coal production, and mining wastes make the Mountain region a key resource to underpin the development of domestic supply chains to help reduce America's dependence on other countries for these critical minerals necessary for a modern economy, while creating good-paying jobs, and supporting communities that historically have depended on mining.

Map 4: Critical Minerals and Materials Potential

The Mountain region is well positioned to produce rare earth elements and other critical minerals from coal, hard rock mining, and energy and mining waste streams while remediating land and water.

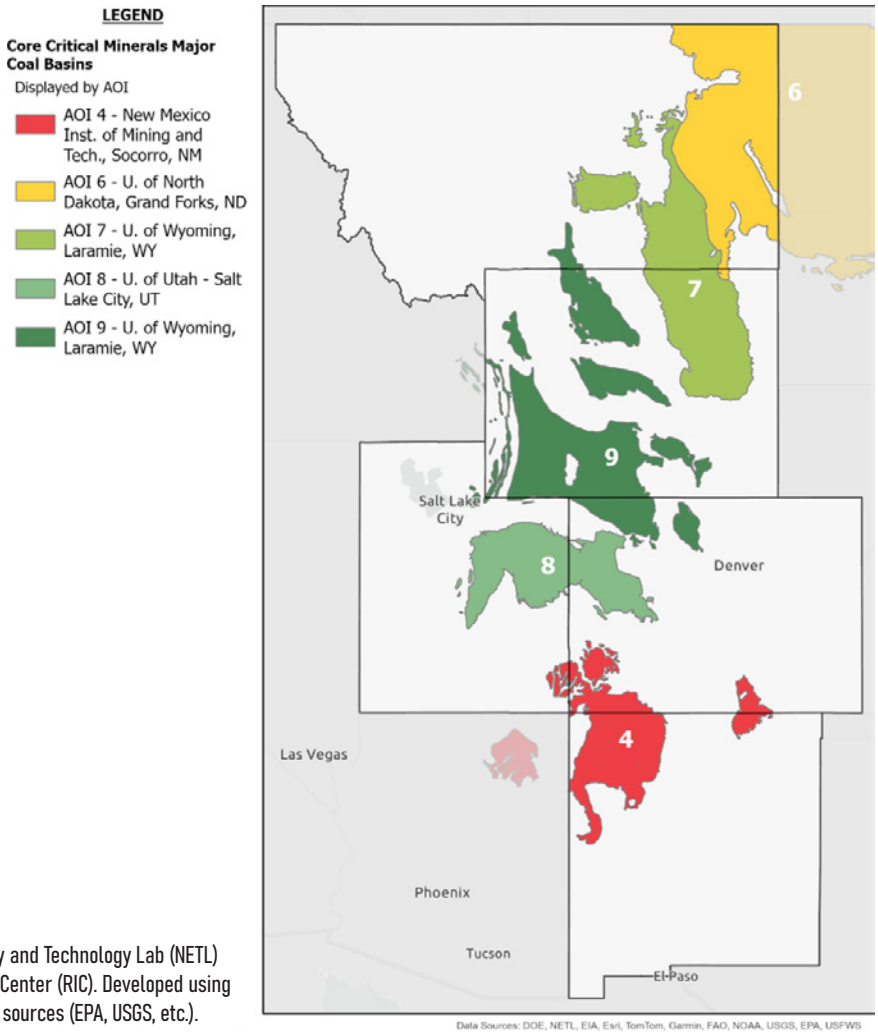


Source: National Energy and Technology Lab (NETL) Research & Innovation Center (RIC). Developed using publicly available data sources (EPA, USGS, etc.).

FECM is already supporting growing activity in the region. For example, FECM and DOE's National Energy Technology Laboratory, with the University of Wyoming, and the Wyoming Integrated Test Center, are developing technologies to produce rare earth elements and other critical minerals from coal, coal by-products, and coal waste while remediating land and water from legacy fossil energy wastes (e.g., coal ash, acid mine drainage, and produced water).

FECM's Carbon Ore Rare Earth and Critical Minerals (CORE-CM) Initiative brings together regional coalitions of universities, industry, state agencies, and others to provide assessments of these feedstocks in coal basins across the country. Four coalitions have been working in the Mountain region (Figure 2) to support the development of domestic critical material supply chains for electric vehicles, wind turbines, valuable carbon products, and other clean energy, defense, and high-tech products used in our everyday lives. Initial estimates suggest that secondary and unconventional sources could provide significant amounts of the rare earth elements and other critical minerals needed to reach the Biden Administration's clean energy and industrial goals. Nationwide, byproducts from just known fossil fuel reserves contain more than 10 million tons of rare earth elements, which is equivalent to more than a 300-year supply at the current rate of U.S. consumption.

Figure 2: CORE-CM Coalitions in the Central Mountain region



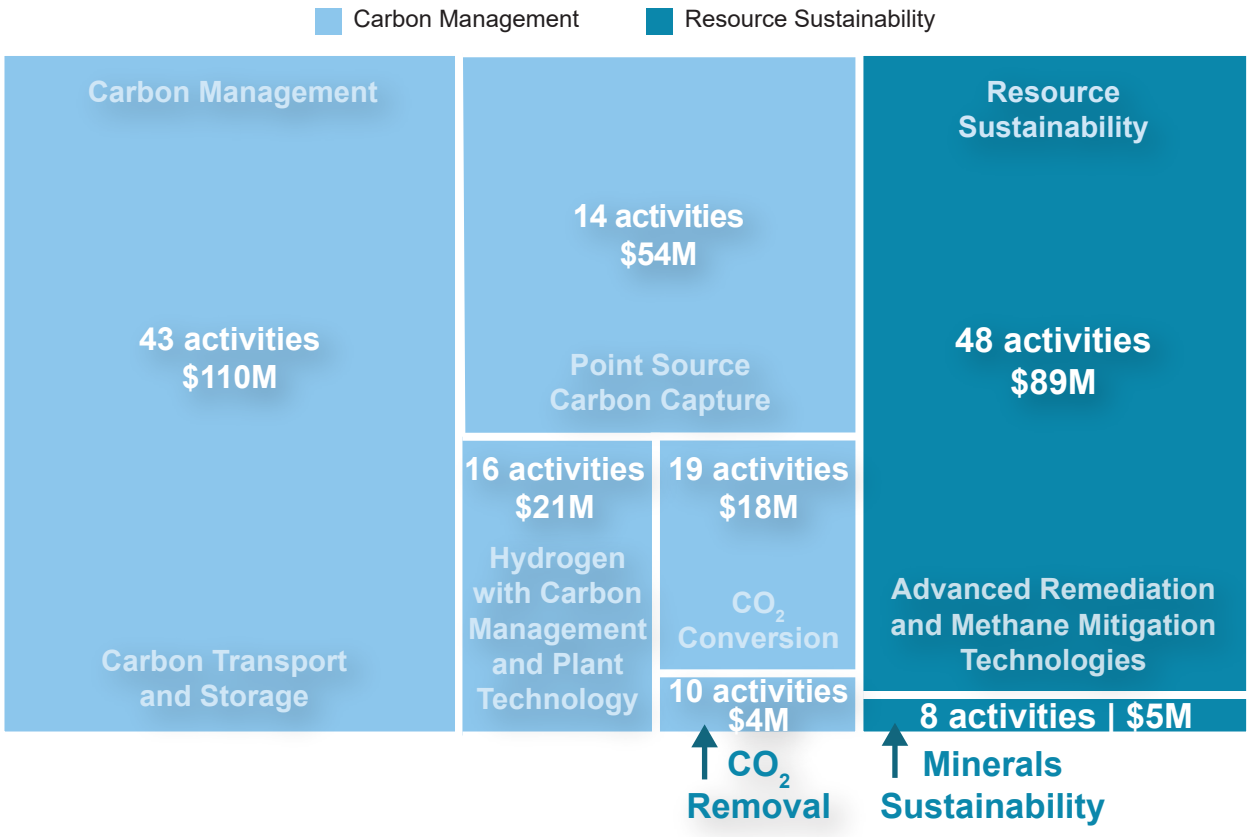
Source: National Energy and Technology Lab (NETL) Research & Innovation Center (RIC). Developed using publicly available data sources (EPA, USGS, etc.).

This is an opportunity to help expand mining to provide the wide range of rare earth elements and critical minerals needed to support fast-expanding clean energy technologies and build a new value-added industry of critical mineral recovery, processing, and refining to the region. Finding new higher-value, non-combustion uses for mined coal and for coal wastes and other energy and mining wastes will also enable the remediation of those wastes and reduce environmental and community impacts in the process. With the investment that DOE is making in the research and development of recovering critical minerals and materials from coal and other mined elements, there is significant opportunity for the mining industry in this region.

Spotlight On FECM Investment and Support in the Mountain Region

FECM has a strong presence in the Mountain region and is supporting innovation to develop and advance technologies and protocols in carbon management and resource sustainability programs. The region hosts 158 project activities valued at $301 million. The individual state shares are: Colorado (53, $140M), New Mexico (37, $69M), Wyoming (28, $53M), Utah (34, $37M), and Montana (6, $1M). Academia leads 69 of these project-related activities; 49 are led by industry; 39 by government entities; and one by an Indian tribe. These projects not only boost innovation but also lead to high-quality and long-term jobs, positioning the region as a hub for sustainable economic growth. The investment is detailed in Figure 3 Distribution of investment across FECM program areas.

Figure 3: Distribution of investment across FECM program areas
(includes value of awards to companies and organizations based in the region, both prime and sub-contracted)



Source: FECM and NETL database

The Mountain region is a well-established energy hub for coal, oil, gas, and electricity and with a long history of mining. The region has established itself as a focal point for both critical minerals and carbon management.

Selected projects shown in Figure 4 represent many opportunities discussed in this paper, including:

- Industrial carbon capture for cement
- Carbon capture for coal-fired and natural gas-fired power generation
- Development of CO_2 regional storage hubs
- Development of regional direct air capture hubs
- Projects to develop critical materials (e.g., graphene) from coal and to separate rare earth elements from coal, coal by-products, and coal waste.

Importantly, although often in early stages, many of these projects have Community Benefit Plans to ensure that projects receiving public funding, particularly from the Bipartisan Infrastructure Law and the Inflation Reduction Act, create economic, environmental, and societal benefits for the communities and workers where projects are located. By fostering collaboration across various sectors and driving transformative research, the region is not only shaping the future of energy, but it has also positioned itself as a model for successful collaboration between academia, industry, and government entities, and communities.

Figure 4: Selection of Key Projects

Point Source Carbon Capture Industrial Sources | Power Sources

- $1.9M for Pre-Feasibility Study of First Commercial Scale Svante Capture Plant for CO_2 storage from cement plant in Colorado
- $91M Large Pilot Testing of the MTR Membrane Post-Combustion CO_2 Capture Process at Basin Electric's 422MW coal-fired power plant, Dry Fork Station, in Gillette, Wyoming
- Several innovative projects with Colorado-based TDA Research on capture of CO_2 from natural gas plants

Hydrogen with Carbon Management Hydrogen Fuel | Gasification | Solid Oxide Fuel Cells & Gas Turbines

- $1.7M to demonstrate the feasibility of sorption-enhanced biomass gasification for production of hydrogen (H_2)-rich syngas in a dual fluidized bed (DFB) reactor
- $2M to demonstrate the technical feasibility of gasifying blends of biomass and high-volume waste materials to produce hydrogen and improve feedstock preparation and feeding to enhance gasifier performance and conversion
- $1.6M to develop a modular, novel, sorbent-based, advanced air separation unit (ASU) for oxygen production to support low-cost hydrogen production from the gasification of biomass and/or wastes

Carbon Dioxide Removal Direct Air Capture with Storage

- Projects studying the feasibility of deployment direct air capture (DAC) hubs in both Pueblo, Colorado ($3M) and Southwest Utah ($2.9M) have been awarded under the BIL Regional DAC Hubs program
- CDR Purchase Pilot Prize has awarded funds for DAC projects expected to be deployed in Colorado as well as terrestrial biomass storage project expected to be deployed in Montana
- DOE funds CDR-related research at the National Renewable Energy Laboratory in Colorado and at Sandia and Los Alamos National Laboratories in New Mexico

Carbon Transport and Storage Monitoring, Verification, Accounting, & Assessment of Long-Term Storage | Storage Infrastructure Demonstration | Accelerating Regional Initiatives | CarbonSAFE

- $19.7M to San Juan Basin CarbonSAFE Phase III: Perform a comprehensive commercial-scale site characterization of storage complex located in northwest New Mexico
- $8M to Uinta Basin CarbonSAFE II: Storage Complex Feasibility Study for commercial CO_2 storage hub
- $17.2M to Wyoming CarbonSAFE Phase III: Accelerating CCUS Commercialization and Deployment at Dry Fork Power Station and the Wyoming Integrated Test Center
- $32.6M to CarbonSAFE Eos: Developing regional Commercial CO_2 storage hub in Southern Colorado

Critical Minerals Efficient Rare Earth Element and Critical Mineral Recovery, Extraction, and Separation | Cost-Competitive Domestic Supply

- $1.3M to support the development of Coal-Deprived Graphene Materials for Industrial Applications with the University of Wyoming
- $1.2M to develop a Machine Learning Screening Tool for Rare Earth Elements and Critical Minerals at the Mine Scale with University of Wyoming
- $1.9M to develop the Ligand-Associated Solid-Liquid Extractuib Media System for Separation of High Purity Individual Rare Earth Elements from Coal-based Resources

Methane Mitigation Advanced Materials | Date Management Tools | Dynamic Compressor R&D | Direct & Remote Sensors | Data Analytics from Point Sources

- $350M in financial assistance to 14 states including Colorado and Utah for the Methane Emissions Reduction Program to support measuring emissions, plugging marginal wells, and installing equipment
- $10M to demonstrate H_2 production using water produced from oil and gas extraction by integrating supercritical water desalination and oxidation with steam methane reforming with Univ. Wyoming
- $1.9M to determine the influence of microstructure on steel lined pipe mechanical property qualification metrics for blended gas environments containing hydrogen with Colorado School of Mines

University Training and Research Education & Training | Novel, Early-stage R&D | Building R&D Capacity | Preparing the Future Workforce

Eleven institutions have been involved in UTR-funded projects

- Central Wyoming College
- University of Utah
- San Juan College
- New Mexico State University
- Southwest Indian Polytechnic Institute
- Navajo Technical University
- Southeast New Mexico College
- University of Wyoming
- Colorado School of Mines
- University of Colorado
- New Mexico Institute of Mining and Technology

Conclusion

The Mountain region has a long history of mining, energy, and industrial production, as well as the exportation of coal, oil, gas, and electricity. Its communities and workforce are rooted in those industries. With the robust framework of federal funding, financing, and incentives for energy and industrial investment now available through the Bipartisan Infrastructure Law and Inflation Reduction Act, it is an exciting time for communities, workers, and businesses in the region.

FECM is committed to supporting economic growth in the region, leveraging its strong mining industry and geological storage potential for new economic opportunities to build clean energy and industrial supply chains, and sustain and create high-wage jobs. FECM's focus areas and portfolio of technologies are well-aligned with the region's energy and industrial mix, local infrastructure, and resources. These efforts will also help the region engage disadvantaged communities, create new jobs, build new supply chains and industry, and invest in supporting university research and development and innovation.

Together, these opportunities will support the Mountain region, leveraging its strengths to advance carbon management and critical mineral development, moving the region forward as it emerges as a leader in the clean energy transition.

The Mountain Regional Report is one of six regional reports that highlight resource sustainability and decarbonization solutions in fossil energy-producing and industrial regions. Given the rapidly evolving market, technology, and policy environment, the regional reports are intended to be "living documents" and will be updated as the outlook on each region evolves. Please note these reports and regional decarbonization workshops do not represent DOE policy or strategy, but rather are a representation of DOE's current understanding based on a synthesis of available facts.

FECM welcomes input and feedback on content for each of the reports. Please direct all inquiries and input to FECMRegionalReport@hq.doe.gov. Input and feedback should not include business-sensitive information, trade secrets, proprietary, or otherwise confidential information. Please note that input and feedback provided is subject to the Freedom of Information Act.

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