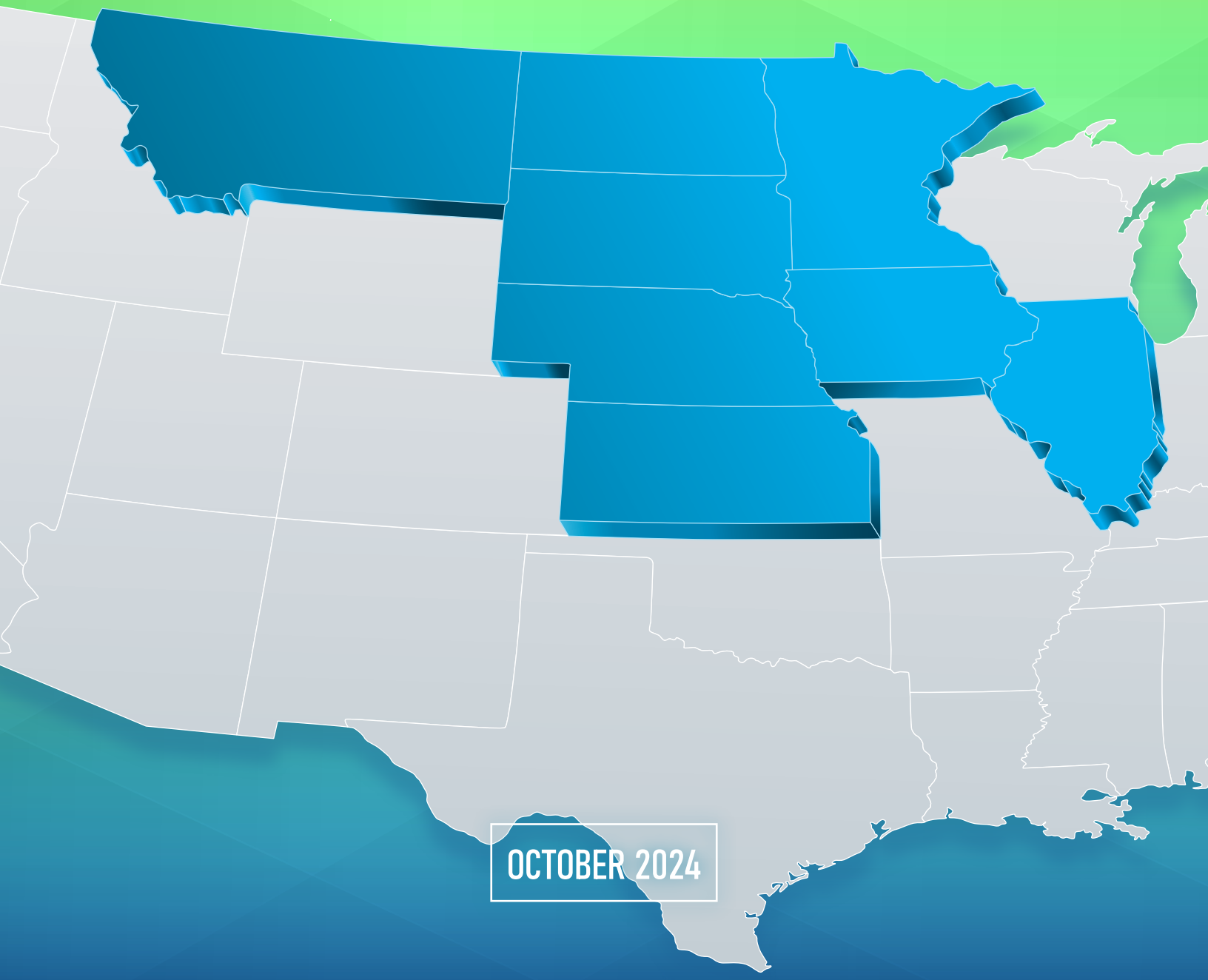
U.S. DEPARTMENT OF ENERGY | Fossil Energy and Carbon Management

HEARTLAND 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

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Purpose of this Report

The "**Heartland 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 Heartland, supporting broader efforts to achieve a clean energy and industrial future. The Heartland region, as defined in this report, includes **Montana, North Dakota, South Dakota, Minnesota, Iowa, Nebraska, Kansas, and Illinois**. It draws on the region's significant traditional and emerging energy resources. Coupled with its significant geological formations and commodities, these resources support current efforts to decarbonize and scale clean energy technologies. Additionally, in addressing the region's unique industry, energy mix, and energy activities, this report identifies priority areas for the Heartland 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 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 fuels while working toward a clean energy and industrial future. Its portfolio encompasses the research, development, demonstration, and deployment of technologies that include carbon capture, carbon conversion, carbon dioxide removal, carbon dioxide transport and storage, hydrogen production with carbon management, methane emissions reduction, and critical minerals production.

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 opportunities available. FECM focuses on two-way engagement, in which communities and stakeholders are not only informed, but they also have the opportunity to 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 Benefit Plan. Ideally, strong Community Benefit 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 Heartland'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 university and private sector research and development and innovation. Further, through DOE's Community Benefit Plans and Community Benefit Agreements, FECM illustrates how the design and scope of a project can maximize economic, environmental, and societal benefits for communities in the state, contributing to project success.

The Heartland – Productive and Sustainable Use of Land for Food and Energy

The Heartland region represents a large rural economy with 35% of U.S. land in farms, and 21% of farms in 2023.[1] Domestic fertilizer production is also growing with 17 awardees of the U.S. Department of Agriculture Fertilizer Expansion Program[2] promoting American-made fertilizer. The program was established following the supply chain disruptions to fertilizer supply to U.S. farmers caused by the Russia-Ukraine war.[3] In addition, this region has 73% of the nation's bioethanol capacity, which also includes the top five bioethanol producing states. In 2022, over 60% of the region's annual electricity came from renewables and nuclear, and the region has some of the best wind resources in the world.

Montana has a long history of coal production, while North Dakota serves as a major hub for oil, gas, and coal production. The Williston Basin, home to the Bakken formation, the second largest tight oil producing formation in the United States, is shared across Eastern Montana and North Dakota. Over the past 10-15 years, North Dakota has experienced a significant amount of growth in oil production. This growth has propelled the state to rank third in the United States for both crude oil reserves and production. Additionally, North Dakota accounts for 2% of the U.S. natural gas reserves and production, and natural gas is shipped through the state from Montana and Canada. North Dakota has been challenged by high rates of flaring of natural gas associated with oil production in the Bakken. Although rates have been on a downward trend in recent years, in 2023, North Dakota ranked in the top three states for flaring and venting, flaring over 5% of gas withdrawals.[4]

Montana and North Dakota each account for about 5% of U.S. coal production through surface mining (i.e., when coal is less than 200 feet underground and large machines remove the topsoil and layers of rock). The coal produced in Montana is subbituminous coal (35-45% carbon) compared to North Dakota's lignite with slightly lower carbon content (25-35%) and heating value. Both states have significant coal deposits, with Montana accounting for approximately 30% of estimated recoverable coal reserves (i.e., coal in the demonstrated reserve base considered recoverable after excluding coal estimated to be unavailable due to land use restrictions, and after applying assumed mining recovery rates), and North Dakota has the world's largest lignite resource.

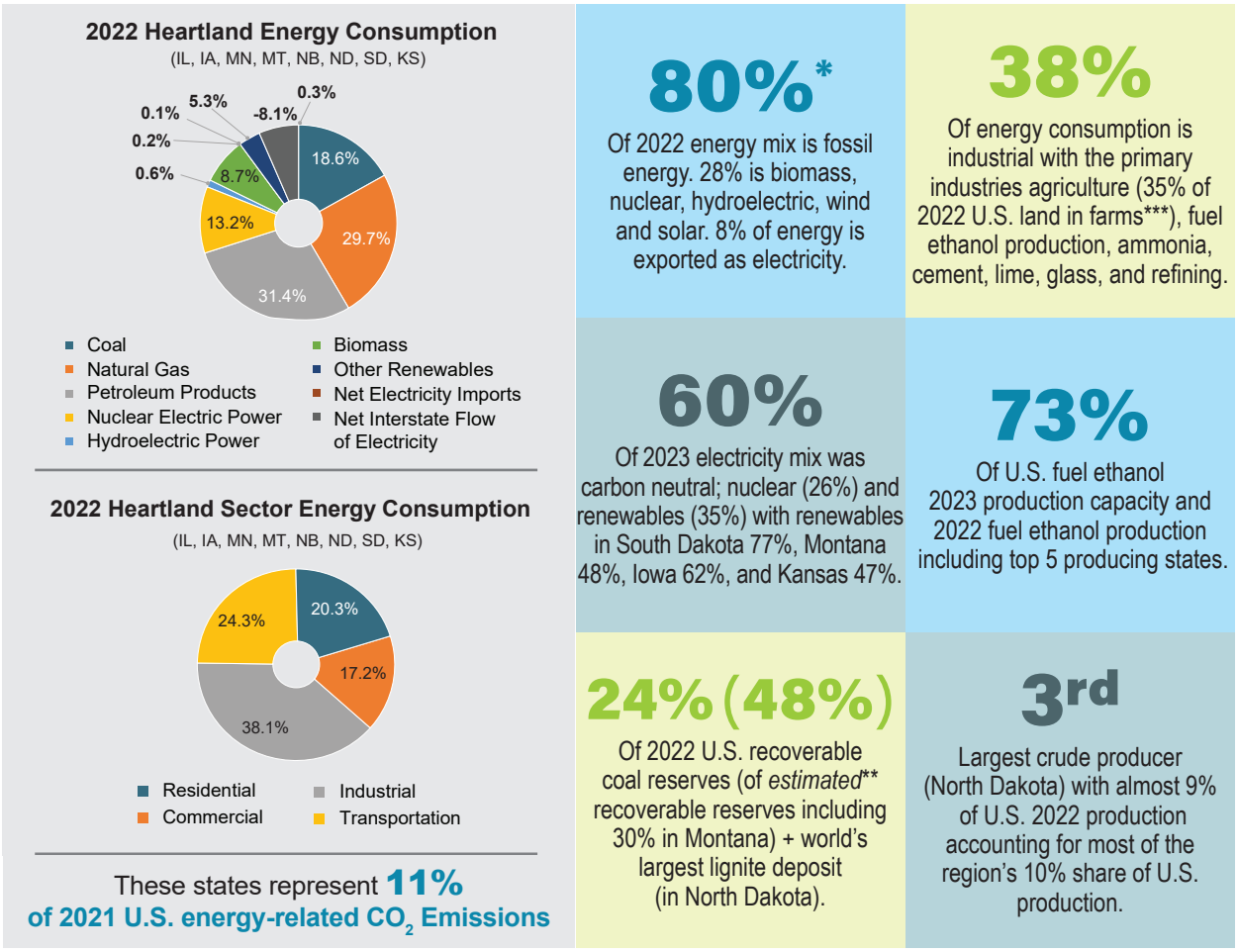
[1] Farms and Land in Farms | National | 2023 | National Agricultural Statistics Service (usda.gov)

[2] FPEP Grants 05.29.24 (usda.gov)

[3] USDA Announces Plans for $250 Million Investment to Support Innovative American-made Fertilizer to give US Farmers more choices in the Marketplace | USDA

[4] Our estimated rate of U.S. natural gas vented or flared declined in 2023 - U.S. Energy Information Administration (EIA)

Figure 1: Energy in the Heartland Region



* Total fossil energy consumption is the sum of the coal + natural gas + petroleum products consumed in the states in the region including fossil energy sources used to generate electricity. Exported electricity, which will be a mix of renewables and fossil souces, is represented as negative consumption (e.g. -8.1%).

** Recoverable coal reserves at producing mines represent the quantity of coal that can be recovered (i.e. mined) from existing coal reserves at reporting mines. EIA's estimated recoverable reserves include the coal in the demonstrated reserve base considered recoverable after excluding coal estimated to be unavailable due to land use restrictions, and after applying assumed mining recovery rates.

*** USDA is the source for the land in farms.

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).

The Heartland Region's energy mix has evolved over the last few decades, leading to substantial growth in the share of wind-generated electricity. Additionally, companies are increasing the energy efficiency and energy productivity of bioethanol production while also integrating biofuels into fuels supply chains. The use of biogas from manure and other wastes in local combined heat and power systems and farm equipment has also increased, resulting in further growth in utilizing waste streams for energy across the region.

Fossil energy still accounts for about 80% of energy consumption in the region because agriculture and transportation make up a large portion of energy consumption and are not easy to electrify. Electrifying agriculture would require switching to electric machinery and equipment that is not economically viable for many farmers. In fact, a significant share of the greenhouse gas emissions from agriculture are not related to the fuel combustion process but methane emissions from animals or nitrogen from fertilizer.

The portfolio of technologies being developed by FECM and other offices across DOE are well-suited to support the Heartland region in diversifying its economy and leveraging its vast rural land and mineral resources to continue to support U.S. energy and food production and security. Additionally, these efforts are further supported by the Bipartisan Infrastructure Law and the Inflation Reduction Act. The funding, tax provisions, and incentives in this legislation are helping to enable a robust market for clean energy and industrial projects. This framework includes tax credits that support businesses in the carbon management and critical minerals industries, offering significant support to the continued development of the Heartland.

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 Clean Energy Demonstrations (OCED); $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 Act program to extend or enlarge planned carbon transport infrastructure to connect additional CO_2 sources. The Bipartisan Infrastructure Law also allots $8 billion for the Regional Clean Hydrogen Hubs, a program managed by OCED. Of the seven hydrogen hubs selected for funding, at least five have carbon management projects.

Additionally, the federal 45Q tax credit provides up to $85 per metric ton of carbon dioxide (CO_2) captured from industry and power generation for dedicated storage in geologic formations, $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 reduction), and up to $180 per metric ton for direct air capture facilities with dedicated storage in geologic formations. Enhancements to the tax credit include: an authorization of the credit for a full ten years (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 has has more than doubled since 2019, with a cumulative total of 219 projects. Of the 219 projects, 59 (27%) are in the Heartland region.[5] In 2023 alone, over $6.5 billion was invested in carbon management in the U.S., about 13% went to the Heartland region.[6] The application queue for Class VI wells is another indicator of activity. Currently, 149 well applications are under review by the Environmental Protection Agency (EPA) across the U.S., and several are located in the Heartland region.[7]

For critical minerals, 45X tax credit provides a 10% credit for the production of 50 different minerals that are essential to our clean energy economy and national security. For clean hydrogen, 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 hydrogen eligible for the tax credit.

[5] 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

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

[7] U.S. EPA Class VI Permit Tracker as of September 13, 2024. (Current Class VI Projects under Review at EPA | US EPA)

Industry

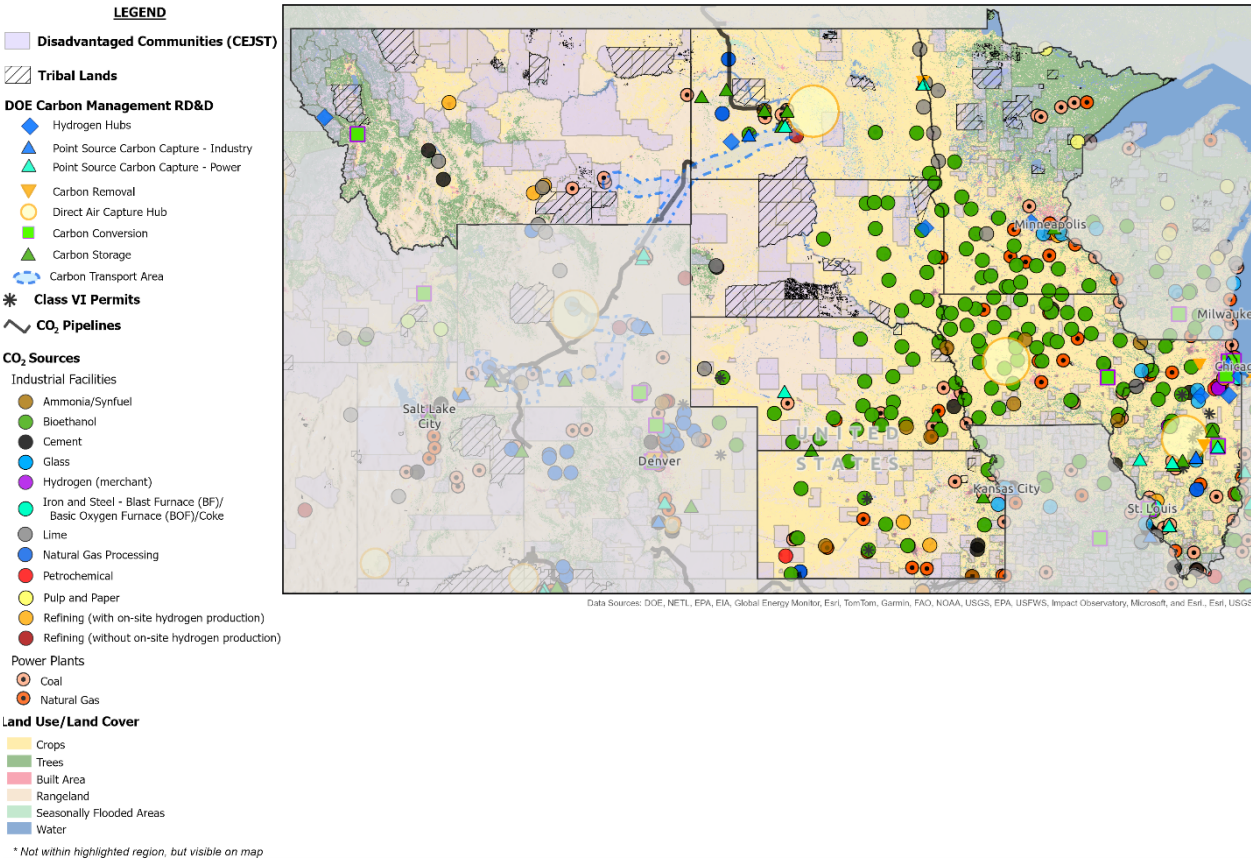
Industrial activity in the Heartland centers around productive use of land resources for food and energy, including agriculture, bioethanol, ammonia, cement, lime, glass, and refining.

As depicted on Map 1, agriculture (which includes crops, dairy, and livestock) and bioethanol production make up a large share of industry in the Heartland region. The implementation of large-scale regional projects, such as the Heartland Hydrogen Hub (HH2H) selected for the DOE Regional Clean Hydrogen Hubs program managed by the Office of Clean Energy Demonstrations (OCED), coupled with the region's rich renewable and biomass resources, will enable industries in the region (e.g., bioethanol, ammonia, cement, lime, glass, and refining) to decarbonize more rapidly. Carbon transport and storage infrastructure can also be shared with future direct air capture hubs.

The first feasibility study for developing the Prairie Compass Hub to demonstrate lower-cost direct air capture technology and storage facilities on the northern Great Plains was selected in the Regional Direct Air Capture Hubs Program. These hubs will create additional pathways to decarbonize existing infrastructure in the near-term and use captured CO_2 as feedstock for low carbon fuels and chemicals. DOE is investing in bold industrial decarbonization technologies at each stage of the innovation pipeline to help manufacturers and businesses use clean energy, increase efficiency, and integrate new, innovative processes and technologies.

Map 1: Industrial Activity in the Heartland

With 73% of the U.S. bioethanol capacity, there is the opportunity for carbon management to reduce bioethanol emissions and support new areas, e.g., sustainable aviation fuels, use of waste and perennial, cover, and purpose-grown crops for low carbon fuels and chemicals.



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

Bioethanol produces one of the most concentrated streams of CO_2 of any industry through fermentation, making carbon capture and storage projects more readily commercially feasible, especially with the 45Q tax credit. North Dakota's first operational, commercial scale CO_2 capture and storage project in the state's bioethanol industry at Red Trail Energy highlights this potential. This project, which captured emissions from bioethanol production, was supported by a partnership between the North Dakota Industrial Commission's Renewable Energy Program and DOE.

Using bioethanol as a feedstock for sustainable aviation fuel is an important decarbonization pathway for fuels that also has near term economic value for growers. Sustainable aviation fuel is one of the few decarbonization technology solutions available for aviation. Coupling carbon management with fuel production will reduce emissions even further. Reducing the greenhouse gas footprint of bioethanol will provide increased financial benefit through state low-carbon fuels standards and support increases in renewable fuel standard blending levels.

Research and development is underway to develop CO_2 as a feedstock to produce economically valuable products such as chemicals, fertilizer, fuels, building materials, plastics, and bioproducts. In addition to supporting the retrofit of refineries to produce lower carbon products, FECM is collaborating with DOE's Bioenergy Technology Office (BETO) in the Office of Energy Efficiency and Renewable Energy. One of BETO's research projects[8] aims to produce chemicals with reduced carbon intensities. The objective of the project is to conduct a feasibility study for converting waste CO_2 from bioethanol production to a value-added plastics monomer through an electrochemical process.

With the significant availability of waste from agriculture and forestry, there is also the opportunity to produce even lower emission products using biomass waste as a feedstock for multiple technologies (e.g., gasification, pyrolysis, and biochemical conversion) and couple it with carbon capture and storage. DOE estimates that about 62%[9] of U.S. agriculture waste and 4.5%[10] of the U.S. forestry waste (e.g., hardwood, mixed wood, and softwood) is in the Heartland region. This opportunity also includes wood waste and wood products that may not be suitable for other uses, such wood waste resulting from emerald ash borer damage.[11]

Additionally, the flexibility of natural gas power generation has played a key role in facilitating the record wind penetrations in the region, meaning that electricity from natural gas increases when wind is low and decreases when wind is high. This has enabled wind in 2023 to account for approximately 60% of electricity in Iowa, 55% in South Dakota, and 46% in Kansas. A significant portion of the region, encompassing North Dakota, South Dakota, Nebraska, Kansas, most of Iowa, and parts of Montana, share transmission lines and belong to the Southwest Power Pool. This entity reached a record wind penetration of 88.5% on March 29, 2022,[12] and it has the highest annual average wind market share of electricity of all U.S. regional transmission operators at 38%.[13]

However, in 2023, natural gas accounted for only 13% of the region's electricity generation while coal-fired generation accounted for 26%, with higher coal-fired electricity shares in Montana (45%), Nebraska (45%), and North Dakota (55%). Further decarbonization of the power sector will require the deployment of carbon capture on both natural gas power plants and coal-fired power plants. For example, the DOE-funded Project Tundra, a carbon capture system that will be developed adjacent to a coal-fired power plant in North Dakota, is a full-scale commercial retrofit that will add valuable near zero-carbon dispatchable capacity to the region.

DOE is also investigating carbon capture technologies to operate flexibly to support variable renewables. There are examples in other markets who will operate fossil energy plants with carbon capture to work with variable wind resources. For example, the United Kingdom has developed a Dispatchable Power Agreement Carbon Capture and Storage business model to enable natural gas with capture to continue to support the growth in wind and solar.

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[8] 2638-1571_RenewCO$_2$_Inc_Subtopic_Area_4_SummaryAbstract.pdf (energy.gov)

[9] BETO: Billion-Ton 2023 | Department of Energy – near-term, $70 per dry ton, waste from agriculture (barley straw, corn stover, oat straw, wheat straw, sorghum stubble, rice straw, pruning residues, rice hulls, cotton field residues, cotton gin trash).

[10] BETO: Billion-Ton 2023 | Department of Energy – near-term, $70 per dry ton, forestry waste (hardwood, mixed wood, softwood)

[11] Twin Cities Metro Area Emerald Ash Borer Wood Waste Study, December 2022.

[12] https://www.spp.org/news-list/spp-sets-regional-records-for-renewable-energy-production/

[13] https://www.spp.org/news-list/spp-sets-regional-records-for-renewable-energy-production/

The carbon management infrastructure needed to realize the decarbonization opportunities in this region has the potential to benefit landowners, including farmers and ranchers, through direct compensation, as well as local and tribal communities, by bringing local economic development, jobs, and reskilling opportunities. Leading bioethanol producers see the economic and climate opportunity and have signed on to regional CO_2 transport and storage projects, but there are mixed views in the wider landowner community. National advocacy organizations that oppose both bioethanol as an alternative fuel and the carbon capture and storage industry have aligned themselves with local landowners who are strongly opposed to the use of eminent domain to secure the land rights needed for pipeline construction. Their opposition is gaining traction: a March 2023 poll from the Des Moines Register found that 78% of Iowans oppose the use of eminent domain for building pipelines.[14] Therefore, developers should also consider alternative methods to eminent domain such as negotiated purchases/leasing and adequate compensation of landowners for carbon management infrastructure passing through their land.

Additional concerns include pipeline safety, particularly in small towns that rely on volunteer fire departments, and long-term impacts on the productivity and value of agricultural lands. Further complicating the implementation of multi-state projects is that the regulatory framework for carbon management varies by state, making the risks and benefits of project development unclear to landowners and communities.

Early and ongoing two-way engagement can be a tool for de-risking potential carbon management projects in this region. This engagement should be well-rounded—providing education on proposed technologies, federal and state laws that govern them, anticipated economic and job creation benefits, as well as information on potential risks and how they can be managed. Developers should also consider, in consultation with communities, how to support local economic development, through jobs and reskilling opportunities and other means. For example, the OCED-selected Heartland Hydrogen Hub (HH2H) alone is anticipated to bring upwards of 3,880 direct jobs, including both construction and permanent jobs. Further, being willing to address input through project design and community benefit and workforce agreements is considered a best practice for operationalizing community engagement.

[14] Weisman, J. (July 20, 2023) New York Times. Left-right alliance against Iowa's CO_2 pipelines.

Energy and Resources

High concentration bioethanol plants (and other emitters) that could share transport to CO_2 storage in the region, coupled with fiscal incentives, results in competitive $/metric ton of CO_2 abated for bioethanol producers and other nearby facilities.

The Heartland region has a significant role in domestic energy production. It includes 32%[15] of U.S. wind capacity, 73% of U.S. bioethanol capacity, and 10% of U.S. crude production. Increasing the share of bioethanol in gasoline helped alleviate supply shortages across the region when gasoline prices were high in 2022. In addition to bioethanol production, the region is expanding its production of other biofuels. LPO has a conditional commitment for a loan guarantee of up to $1.44 billion to Montana Renewables, LLC (MRL) to help finance the expansion of a renewable fuels facility in Great Falls, Montana, that will utilize vegetable oils, fats, and greases to produce sustainable aviation fuel (SAF), renewable diesel (RD), and renewable naphtha (RN).

Renewable natural gas is also an opportunity in the region. Livestock in the Heartland generates about 34% of the total U.S. beef, swine, and dairy manure.[16] Combined with wastewater and municipal solid waste in landfills, there could be significant renewable gas produced in the region. This renewable gas could be used in distributed combined heat and power plants, replace diesel in medium and heavy-duty trucks and stationary equipment, or injected into the natural gas pipelines and blended to reduce the overall emissions intensity of piped natural gas.

The region also plays a critical role in food security due to its role in agricultural production and as home to ten ammonia plants.[17] The Russian invasion of Ukraine impacted the supply of internationally imported fertilizer, resulting in increased support for American made fertilizer. It also presented an opportunity to lead the world in the production of near-zero carbon ammonia through deployment of carbon capture and storage at existing and new fertilizer production capacity. There will be additional investment in the region's fertilizer production as well, including the 17 awardees of the Rural Development U.S. Department of Agriculture Fertilizer Expansion Program.

North Dakota, as one of the largest producers of crude oil, has been working to reduce the environmental impacts of crude oil production. Under DOE's Advanced Remediation Technologies Program, FECM has invested over $28 million in four Heartland Field Test Sites, mostly focused on the optimization of enhanced oil recovery technologies, processes, and tools. Results from these projects have led to optimized well completion design, increased operational efficiency, and the identification of potential reductions in freshwater use, therefore reducing associated environmental impacts.

Additionally, North Dakota, which ranks among the top three states in the U.S. for volumes of natural gas flared, is developing technology solutions to reduce and, in some cases, eliminate natural gas venting and flaring altogether. For example, under DOE's Methane Mitigation Technologies Research and Development Program, FECM partnered with the University of North Dakota Energy and Environmental Research Center to commercialize the

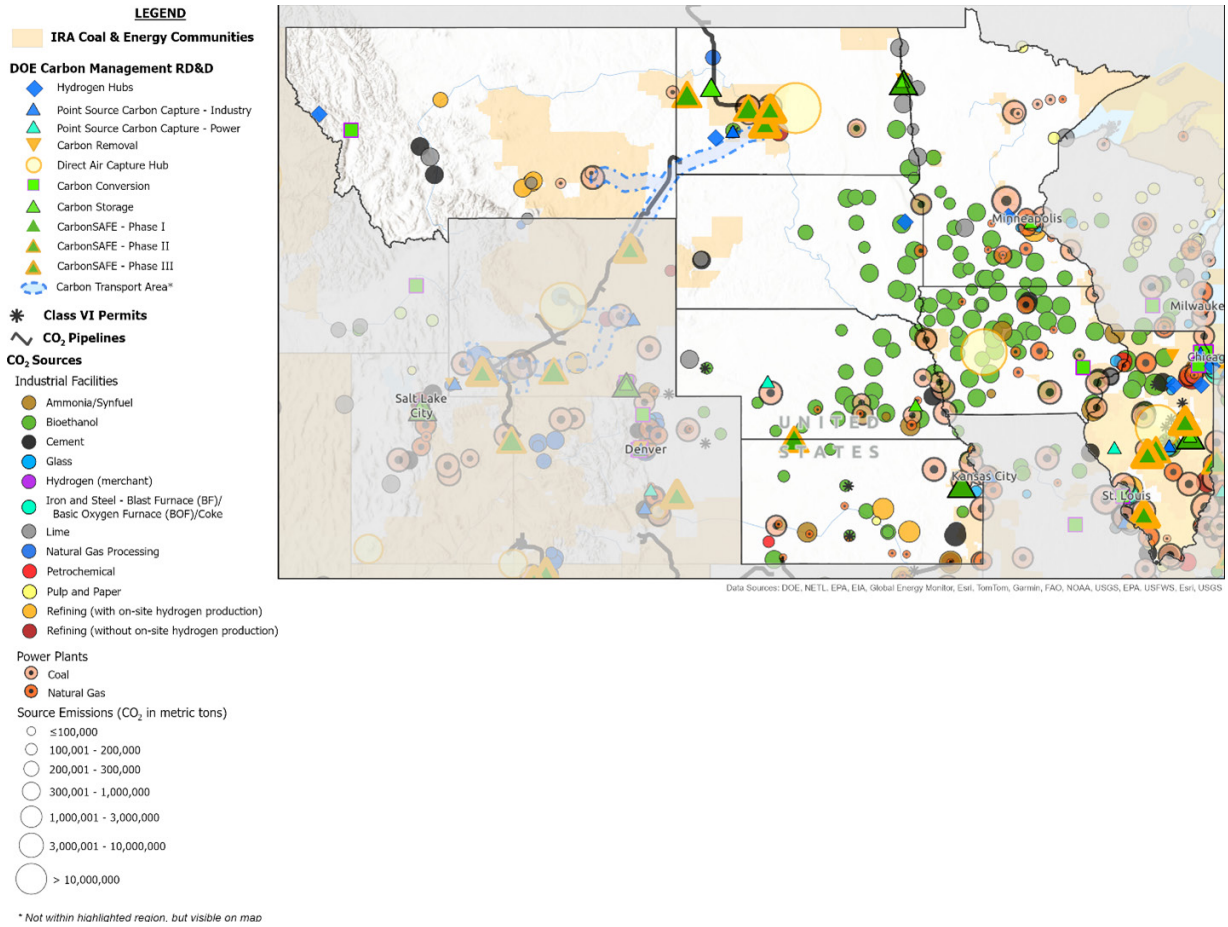
[15] Land-Based Wind Market Report | Energy Markets & Policy (lbl.gov).

[16] BETO: Billion-Ton 2023 | Department of Energy Near-term scenario, 2023, $70, Wastes Resources (Manure Beef, Manure Dairy, Manure Swine).

[17] U.S. Environmental Protection Agency Facilities Database.

Map 2: Energy Infrastructure and Resources in the Heartland

The concentration of CO_2 sources, particularly bioethanol, creates an economic opportunity for facilities in the region to aggregate CO_2 through common transport infrastructure to shared storage sites.



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

Polar BearSM technology designed to eliminate natural gas venting and flaring from thousands of low producing oil and gas facilities located throughout the Heartland region. The University of North Dakota also received a grant under FECM's University Training and Research Program to perform an engineering design and economic analysis study on the conversion of associated gas in the Bakken Formation to high-value carbon black and hydrogen.

As shown on Map 2, there are DOE-funded commercial scale CO_2 storage activities and Class VI permits underway across the region, with some of the most advanced in Kansas, Illinois, and North Dakota. Two ethanol facilities in Kansas have been capturing CO_2 and using the CO_2 for enhanced oil recovery for more than a decade—Arkalon which came online in 2009 and Bonanza which started operations in 2012.[18] The Archer Daniel Midlands' Project Landing started in 2009 and has been capturing and storing CO_2 from its corn ethanol plant in Illinois.[19] In North Dakota, DOE funded the initial engineering design and estimated cost for capture

[18] Bioenergy and Carbon Capture and Storage (globalccsinstitute.com).

[19] Project Landing Page | netl.doe.gov.

and compression of CO_2 generated from Red Trail, an operational ethanol production facility.[20] In the region, there are saline formations and conventional oil and gas fields that offer the potential to store up more than 130 billion metric tons of CO_2[21] from power plants and industrial facilities. There is also an opportunity to store the CO_2 removed from the atmosphere via direct air capture. For example, North Dakota's CO_2 storage capacity significantly exceed its emissions, enabling it to build infrastructure to provide carbon management services to other states in the region that lack comparable geologic storage potential. This creates a promising future economic opportunity that adds to the state's expertise and workforce in the oil and gas industry.

Developers whose projects proceed either with or without federal funding can refer to FECM's "Responsible Carbon Management Initiative" as a guide for safety, environmental stewardship, transparency, and community engagement and benefits in project development. This initiative builds on DOE's long history of research and development regarding carbon storage safety. In 2003, DOE started regional research and development efforts on carbon storage and completed a series of successful projects in the region. In 2016, the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Program was launched to support the commercial development of geologic storage. The program provides projects crucial resources and information necessary for large-scale geologic storage facilities or carbon management hubs. The national network of CarbonSAFE projects is on track for targeted commercial injectivity at the 100 million metric tons per year scale and to identify contingent storage resources[22] at the 6 billion metric tons scale by 2035. These projects are designed to support public engagement and dialogue activities, offering technical assistance and resources to communities.

In addition to leveraging the energy workforce in North Dakota, there is a significant opportunity to train new workers which will expand skillsets and career opportunities in the region. The Rhodium Group and Great Plains Institute estimates that carbon capture and storage, in Montana, North Dakota, South Dakota, Minnesota, Iowa, Nebraska, Kansas, and Illinois, could create over 20,600 annual construction and operations jobs, helping to ensure the Heartland community benefits from the construction and operations of carbon management technologies. There is also a significant opportunity to expand the skillsets and career opportunities of industrial workers in the region. Targeted workforce development and training will be needed to transition the workforce to new technologies.

[20] Initial Engineering and Design for CO_2 Capture from Ethanol Facilities (energy.gov).

[21] Fact Sheet: The Inflation Reduction Act and Carbon Management Opportunities in North Dakota (energy.gov).

[22] 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)

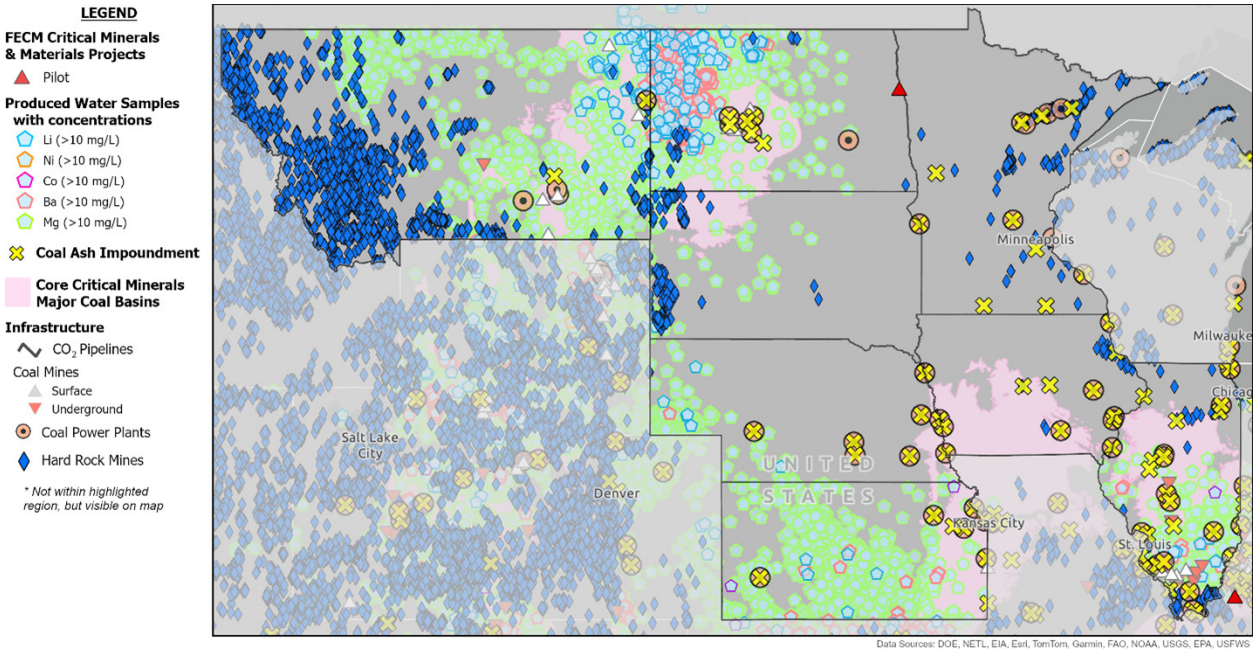
Recovery of Critical Minerals

Coal, coal byproducts, and coal and energy wastes in the Heartland are rich in the critical minerals needed for clean energy technologies and our nation's defense.

The Heartland has an opportunity to play a key role in developing domestic sources of critical minerals and materials and rare earth elements. Critical minerals and rare earth elements are key to our national defense and to manufacturing clean energy 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. Demand for critical minerals and materials and rare earth elements is growing in the United States and globally, and our nation currently imports greater than 80 percent of its rare earth elements from non-domestic suppliers. As part of the wider all government effort to increase the domestic mining and production of critical minerals, DOE's Office of Fossil Energy and Carbon Management is pursuing research to recover rare earth elements and critical minerals from coal, coal-related wastes, and other energy and mining waste streams to develop a domestic supply chain of critical minerals and rare earth elements that will reduce U.S. dependence on foreign sources.

Map 3: Critical Minerals and Rare Earth Elements Potential

With 48% of the U.S. recoverable coal reserves and as the 3rd largest crude producer, the Heartland Region has the opportunity to produce rare earth elements and critical minerals from coal and energy waste streams, including coal ash, acid mine drainage, and produced water.

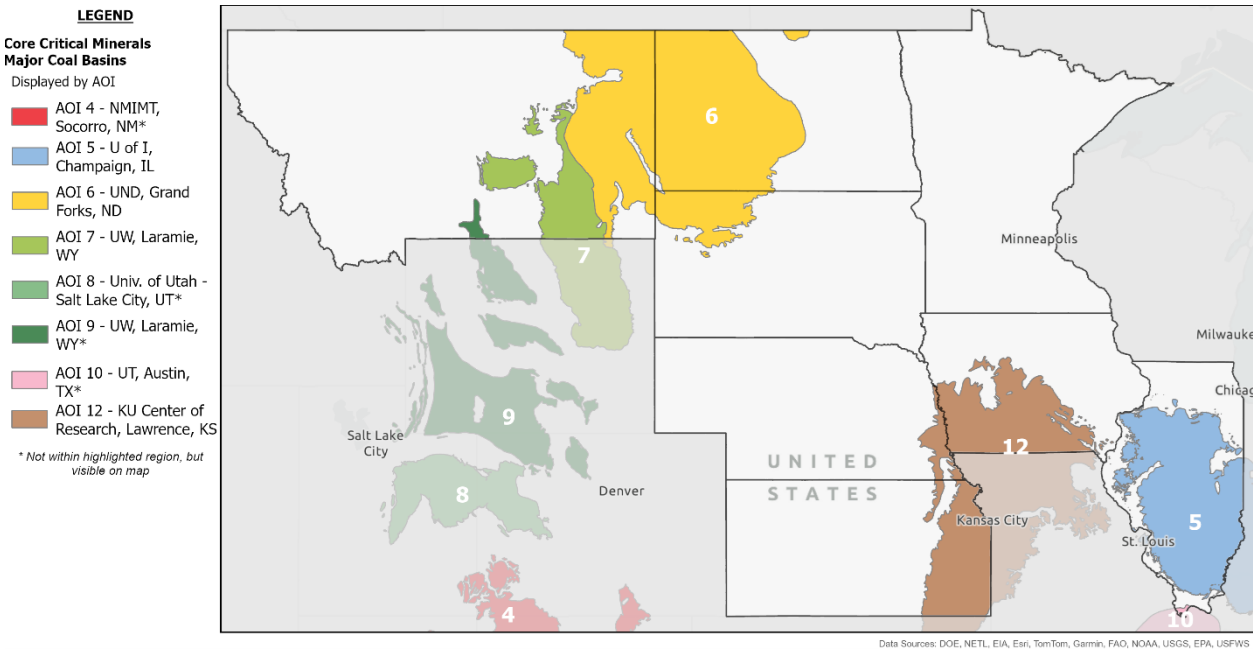


Source: National Energy and Technology Lab (NETL) Research & Innovation Center (RIC). Developed using publicly available data sources (EPA, USGS, etc.).

For the past decade, FECM and DOE's National Energy Technology Laboratory have been developing technologies to produce rare earth elements and critical minerals from unconventional feedstocks while remediating land and water from energy and mining byproducts and wastes (e.g., coal, coal ash, acid mine drainage, and produced water). One of the nation's first-of-a-kind pilot facilities to generate individually separated, high-purity rare earth oxides and salts from newly mined lignite coal and the surrounding clay layers was built in this region. A front-end engineering design study is currently being developed for a large-scale demonstration facility from similar feedstocks, which if successful, could lead to the building of such a facility in this region.

FECM's Carbon Ore Rare Earth and Critical Minerals (CORE-CM) Initiative brings together coalitions of universities, industry, state agencies, and others to provide an assessment of these feedstocks in coal basins across the country. Four different coalitions are working in the Heartland alone (reference Map 4) to evaluate the potential for coal, coal wastes, and other secondary and unconventional resources in the region to support domestic supply chains for new, high-value and high-volume carbon products, as well as other clean energy, defense, and high-tech devices used in our everyday lives.

Map 4: CORE-CM Coalitions in the Heartland Region



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

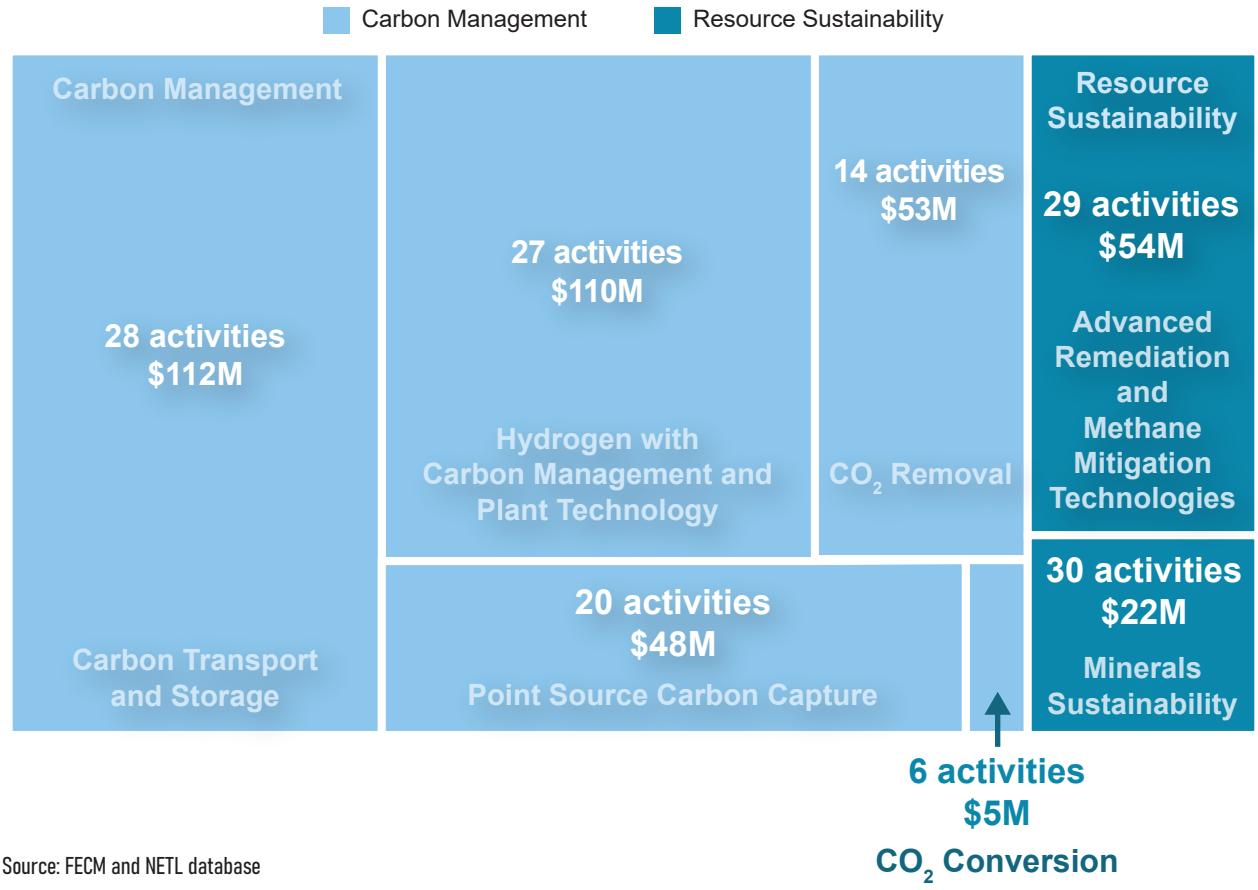
This is an opportunity to help bring a new industry of critical mineral recovery, processing, and refining to the Heartland region, find a new use for coal wastes that otherwise would be discarded, and help remediate legacy ash and mine wastes where they remain an environmental problem in the region. Initial estimates suggest that unconventional and secondary sources could provide significant amounts of the rare earth elements and other critical minerals needed to meet projected growth in future U.S. demand. Nation-wide, wastes and byproducts from fossil energy, mining and other industries currently contain more than ten million tons of rare earth elements, which is equivalent to an over 300-year supply at the current rate of U.S. consumption.

Spotlight on Investment and Support in the Heartland Region

FECM has a strong presence in the Heartland and is working with the region to develop and advance technologies and protocols in carbon management and resource sustainability. As shown in Figure 2, the program areas that account for the largest value to the region (represented by organizations and companies based in the region working on FECM projects) are carbon transport and storage and hydrogen with carbon management. Given the opportunities discussed here, DOE expects investments from our point source carbon capture, carbon conversion, and minerals sustainability program areas to grow.

As of May 2024, , the region currently hosts 154 DOE-funded project activities valued at $414 million, primarily in Illinois (64 projects, $188 million), North Dakota (49 projects, $165 million), Kansas (14 projects, $31 million), Minnesota (7 projects, $18 million), Nebraska (7 projects, $8 million), Iowa (7 projects, $2.5 million), and Montana (6 projects, $1.4 million). Figure 6 illustrates the total award value by FECM's research programs.

Figure 2: 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 projects led by entities based in the Heartland region are advancing many of the opportunities discussed in this paper, including:

- Three carbon storage hub projects with the Batelle Memorial Institute, University of North Dakota, and University of Illinois,
- Pre-front end engineering and design for carbon capture at a Red Trail Energy Bioethanol Plant at the University of North Dakota,
- Fluidized bed gasification for conversion of biomass and waste materials to renewable hydrogen with GTI Energy in Des Plaines, Illinois, and
- Pilot-Scale facilities producing high purity, mixed rare earth oxides/critical minerals (Co, Mn, Ni, Ga, Gd) from domestic coal-based sources at the University of North Dakota.
- Heartland Hydrogen Hub (HH2H).

Importantly, although often in early stages, many of these projects have Community Benefits 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 3: Selection of Key Projects Funded by FECM

Point Source Carbon Capture Industrial Sources | Power Sources

- $4M for University of Illinois to lead a FEED study for capturing CO_2 from a hot briquetted iron facility
- $1.6M for University of North Dakota to lead a pre-FEED for carbon capture at an RTE Ethanol Plant
- A total of $56M for FEED studies/small-pilot testing of capturing CO_2 from gas/coal-fired power generation in IL and ND
- A total of $89M for University of Illinois/University of North Dakota to lead pilot-scale demonstations of capturing CO_2 from gas/coal-fired power generation in IL and ND

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

- $25.7M to University of Illinois, Front-End Engineering Design Study for Hybrid Gas Turbine and Ultra-Supercritical Coal Boiler Concept Plant with Post Combustion Carbon Capture
- $2M to Gas Technology Insititute, Fluidized Bed Gasification for Conversion of Biomass and Waste Materials to Renewable Hydrogen
- $2.1M to University of North Dakota, Modular Biomass Gasification for Co-Production of Hydrogen and Power
- Heartland Hydrogen Hub*

  **OCED selected*

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

- $13M to Battelle Memorial Institute, Integrated Midcontinent Stacked Carbon Storage Hub
- $16.6M to University of North Dakota, Roughrider Carbon Storage Hub
- $19.2M to University of Illinois, Illinois CarbonSAFE: Illinois Storage Corridor

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

- Recently selected University of Illinois to perform a FEED study to produce Critical Minerals and Materials from coal-based resources to establish a fully integrated, vertical supply chain for several critical minerals found entirely within Illinois. The objective is to produce lithium, scandium, neodymium and praseodymium, high-purity dysprosium, as well as other rare earth oxides, nickel, zinc, cobalt, manganese, and potentially high-purity aluminum

Advanced Remediation Environment Impacts of Development | Reducing Land and Water Impacts through Improved Recovery Efficiency | Abating Climate Risk from Oil and Gas Resources | Repurposing Existing Infrastructure

- $29.3M for Hydraulic Fracturing Test Sites 1 & 2 to improve resource recovery efficiency and minimize current and future air and water quality impacts
- $7.8M for Field Evaluation of the Caney Shale as an Emerging Unconventional Play
- $7.8M for the Austin Chalk/Eagle Ford Field Laboratory
- $3.3M for Tuscaloosa Marine Shale Laboratory
- $7.9M for Engineered Water for improvement of Oil Recovery for Fractured Reservoirs

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

- $1M to the University of North Dakota EERC to field validate a flare reduction technology
- $5M to Gas Technology Institute to develop methane emissions factors for more than 800 natural gas and oil storage tanks throughout the U.S.
- $1M to Argonne National Laboratory to develop engine retrofit technology to reduce methane emissions from exhaust

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

Four active projects with total award value of nearly $1.9M and least 8 students trained:
University of North Dakota, University of North Dakota Energy and Environmental Research Center

Six additional institutions are past recipients of UTR awards:
Illinois Institute of Technology, Iowa State University, Southern Illinois University, University of Illinois, University of Illinois-Chicago, University of Nebraska

Conclusion

FECM recognizes that the Heartland is a region of farmers, ranchers, landowners, and tribal entities who over generations have been custodians of the nation's land and food. Moreover, with the regions increasing focus on bioethanol production, oil shales, wind energy, and critical minerals, the region holds significant traditional and emerging energy resources. These resources, coupled with significant geological formations and commodities, support current efforts to decarbonize and scale clean energy technologies. Further, 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 the Heartland and the unique challenges of its vast rural landscape. FECM's focus areas and portfolio of technologies is well-suited to the region's energy and industry mix, in addition to its local infrastructure and resources. Together, these opportunities will support the Heartlands, leveraging its strengths to advance a range of carbon management and resource sustainability solutions, moving the industry forward as it emerges as a leader in the clean energy and industrial transition.

The Heartland 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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