



CARBON CAPTURE, UTILIZATION, AND STORAGE IN ILLINOIS

**Prairie Research Institute
University of Illinois Urbana-Champaign**

CARBON CAPTURE, UTILIZATION, AND STORAGE IN ILLINOIS

Acknowledgements

Through Public Act 102-0341, the Illinois General Assembly directed the Prairie Research Institute (PRI) at the University of Illinois Urbana-Champaign, in consultation with an inter-governmental advisory committee, to file an objective, science-based report on the potential for carbon capture, utilization, and storage as a climate mitigation technology throughout Illinois.

The Prairie Research Institute wishes to thank the members of the intergovernmental advisory committee for their assistance:

- State Rep. Ann Williams (11th District) – co-chair
- State Rep. Tom Bennett (106th District) – co-chair
- Andrew Armstrong, Chief, Environmental Bureau, Illinois Attorney General's Office
- Rob Baren, Legislative Liaison, Illinois Department of Agriculture
- Colleen Callahan, Director, Illinois Department of Natural Resources
- Adnan G. Khayyat, Chief, Division of Nuclear Safety and Chief Strategy Officer, Illinois Emergency Management Agency
- Kyle Rominger, Chief, Bureau of Land, Illinois Environmental Protection Agency
- Katherine Stonewater, Senior Advisor, Energy and Broadband, Illinois Department of Commerce and Economic Opportunity
- Illinois State Sen. Craig Wilcox (32nd District)

PRI also thanks stakeholders who submitted comments and attended listening sessions, as well as the citizens of the state of Illinois.

Suggested Citations

Carbon Capture, Utilization, and Storage in Illinois and *Carbon Capture, Utilization, and Storage in Illinois: Law and Policy Supplement* were submitted to the Governor and the Illinois General Assembly on Dec. 16, 2022 and were made publicly available on Jan. 9, 2023.

Greenberg, S., Whittaker, S., and OBrien, K. (2022). *Carbon Capture, Utilization, and Storage in Illinois*. Champaign, IL : Prairie Research Institute. <https://hdl.handle.net/2142/116416>

Hemrich, V.E. (2022). *Carbon Capture, Utilization, and Storage in Illinois: Law and Policy Supplement*. Champaign, IL : Prairie Research Institute. <https://hdl.handle.net/2142/116416>

TABLE OF CONTENTS

SECTION

1

AUTHORS..... vi

Contributorsvi

SECTION

2

ACRONYMS, ABBREVIATIONS, AND ICONS..... vii

SECTION

3

EXECUTIVE SUMMARY viii

Considerations and Recommendations	x
Infrastructure	x
Capture and Utilization	xi
Transport	xi
Storage	xi
Permitting under UIC Class VI	xii
Economic Considerations	xii
Energy and Climate Policy	xii
Environmental Protections and Environmental Justice	xiii
Communication and Public Engagement	xiii
Stakeholder Engagement	xiii
CO ₂ Storage Safety and Risks	xiv
Human Health and the Environment.....	xiv
Transportation and Pipelines	xv
Property and Ownership.....	xvi
Economic Impact.....	xvii
Permitting.....	xvii
Technology Readiness	xviii
Conclusion	xviii

SECTION

INTRODUCTION 1

SECTION

CARBON CAPTURE 7

Point Source Capture 10
Direct Air Capture 12
Recommendations 13

SECTION

6

CARBON UTILIZATION 14

Recommendations 16

SECTION

CARBON STORAGE 17

Characteristics of Suitable Geologic Storage Complexes..... 18
 Injectivity and Storage Capacity 19
 Containment 20
 Characterization Methods 20
Illinois’ Experience with Carbon Capture and Storage 23
 FutureGen and FutureGen 2.0..... 24
 Illinois Basin – Decatur Project: 2007-2021..... 24
 Industrial Carbon Capture Storage Project 25
 CarbonSAFE..... 27
 Future Storage Projects in Illinois 28
Federal Permitting of Carbon Injection and Storage..... 28
Identifying and Managing Risk Associated with Carbon Storage..... 30
 CO₂ Leakage 31
 Induced seismicity..... 33
Guidance and Best Practices for Carbon Storage..... 34
 U.S. Department of Energy 35
Recommendations 35

SECTION

POLICY CONSIDERATIONS IN ILLINOIS 36

Ownership and Control of Pore Space in Illinois.....	37
Integration and Unitization in Illinois.....	38
Long-term Financial Responsibility for Carbon Storage in Illinois.....	38
Carbon Storage and State-owned Land in Illinois.....	39
State Primacy	40
Recommendations	41
Subsurface Rights.....	41
Permitting.....	41

SECTION

9 ECONOMIC IMPACT 42

Fees and Incentives	46
Illinois Incentives	46
Federal 45Q Tax Credits	47
Federal CIFIA Loan Program	48
Recommendations	48

SECTION

10 TRANSPORT OF CO₂ 49

Federal Regulation of CO₂ Pipelines	50
Illinois Regulation of CO₂ Pipelines	50
Safety.....	51
Eminent Domain.....	52
Recommendations	52

SECTION

11 FEDERAL POLICIES AND PUBLIC-PRIVATE PARTNERSHIP POTENTIAL 53

Recommendations	55
Energy and Climate Policy	55

SECTION 12 STAKEHOLDER ENGAGEMENT AND ENVIRONMENTAL JUSTICE 56

Stakeholder Concerns..... 57

Public Engagement..... 57

Climate Change Impacts..... 57

Pipeline Siting and Safety 57

Property and Ownership..... 58

Permitting..... 59

Other Risk Burdens 59

Environmental Justice 60

Federal Environmental Justice Landscape..... 61

Illinois Environmental Justice Landscape..... 62

Recommendations 63

Environmental Assessments and Environmental Justice..... 63

Communication and Public Engagement 63

APPENDIX A REFERENCES 65

APPENDIX B GLOSSARY 72

AUTHORS

DR. SALLIE GREENBERG is a principal research scientist of Energy & Minerals at the Illinois State Geological Survey (ISGS), part of the Prairie Research Institute at the University of Illinois Urbana-Champaign. Dr. Greenberg acts as a strategic advisor for Energy & Minerals and works on multiple projects, including co-leading the Midwest Regional Carbon Initiative Partnership and the Illinois Corridor CarbonSAFE project. Over the past 20+ years, she led the Illinois Basin — Decatur Project to completion and has consulted or contributed to more than 30 energy and carbon capture and storage projects, especially in project development, risk reduction, and stakeholder engagement. Dr. Greenberg specializes in many areas including strategic development, government relations, energy policy, environmental and social justice, project review, and relationship building. Dr. Greenberg uses her advanced degrees in low temperature geochemistry and education to create strategies for change based on understanding public challenges related to balancing societal demands for energy with environmental concerns. Dr. Greenberg holds a Ph.D. in Secondary and Continuing Education and a Master of Science degree in Geology from the University of Illinois and a Bachelor of Arts degree in Geology from Alfred University in New York.

DR. STEVE WHITTAKER, formerly the director of Energy & Minerals at the Illinois State Geological Survey (ISGS), part of the Prairie Research Institute at the University of Illinois Urbana-Champaign, led a team researching carbon capture and storage (CCS), critical mineral resources, blue hydrogen, energy storage, and carbon utilization. The Energy & Minerals group has led four U.S. Department of Energy (U.S. DOE) CarbonSAFE projects within the Illinois Basin region to evaluate the potential for commercial-scale CCS projects. Previously, he was based in Australia, where he was a research group leader in the Commonwealth Scientific and Industrial Research Organization (CSIRO) and global storage manager with the Global CCS Institute, and in Canada as chief technology manager at the Petroleum Technology Research Centre. He is chair of the ISO 27914 to develop international standards for geological storage of carbon dioxide. Dr. Whittaker is a geologist with a Ph.D. from the University of Saskatchewan, Canada and post-doctoral fellowships at Queen's University and McGill University.

DR. KEVIN C. OBRIEN is the director of both the Illinois Sustainable Technology Center (ISTC) and the Illinois State Water Survey (ISWS), both parts of the Prairie Research Institute at the University of Illinois Urbana-Champaign. These organizations are dedicated to the sustainable use of energy and water resources to drive economic development. One of the major focuses of ISTC has been capturing and utilizing carbon emissions from power plants and industrial sources. Dr. OBrien is the principal investigator (PI) for the largest carbon capture front-end engineering and design (FEED) study in the world and the largest carbon capture pilot in the world (now at a build/operate phase). He also leads the 21st Century Power Plant project, which combines carbon capture, utilization, and energy storage along with a new approach for energy generation. Dr. OBrien is also the PI for scaling-up direct air capture (DAC) technologies for carbon removal at various locations that connect with existing renewable resources.

Contributors

Laura L. Barnes

sustainability information curator, Illinois Sustainable Technology Center, Prairie Research Institute

Angie Coy

coordinator of stakeholder engagement, Prairie Research Institute

Veronica E. Hemrich, Esq.

policy analyst, Prairie Research Institute

Tiffany Jolley

strategic content specialist, Prairie Research Institute

Danielle Ruffatto-Alberts

strategic content specialist, Prairie Research Institute

Lisa Sheppard

media and communications specialist, Prairie Research Institute

Richard Winkel

deputy executive director, Prairie Research Institute

ACRONYMS, ABBREVIATIONS, AND ICONS

45Q: 45Q tax credit

ADM: Archer Daniels Midland

ANSI: American National Standards Institute

AoR: Area of review

BLM: Bureau of Land Management [U.S.]

CarbonSAFE: Carbon Storage Assurance Facility Enterprise [DOE Program]

CEJA: Climate and Equitable Jobs Act

CEJST: Climate and Economic Justice Screening Tool

CEQ: White House Committee on Environmental Quality

CCUS: Carbon capture, utilization, and storage

CFR: Code of Federal Regulations

CIFIA: Carbon Dioxide Transportation Infrastructure Finance and Innovation

CWLP: City Water, Light & Power (Springfield, IL)

CO₂: Carbon dioxide

DAC: Direct air capture

DMC: Dimethyl carbonate

EGU: Electric-generating units

EJ: Environmental justice

EOR: Enhanced oil recovery

FECM: Office of Fossil Energy and Carbon Management [DOE program]

FEED: Front-end engineering and design

GHG: Greenhouse gas

IBDP: Illinois Basin — Decatur Project

ICC: Illinois Commerce Commission

ICCS: Illinois Industrial Capture and Storage Project

IEA: International Energy Agency

IDNR: Illinois Department of Natural Resources

IEPA: Illinois Environmental Protection Agency

IJA: [Infrastructure Investment and Jobs Act](#) 

IPCC: International Panel on Climate Change

ISGS: Illinois State Geological Survey

ISO: International Organization for Standardization

ISTC: Illinois Sustainable Technology Center

ISWS: Illinois State Water Survey

LCA: Life cycle assessment

MGSC: Midwest Geological Sequestration Consortium

MVA: Monitoring, verification, and accounting

MWe: Megawatts electric

NEPA: National Environmental Policy Act of 1969

NETL: National Energy Technology Laboratory

OMB: Office of Management and Budget [U.S.]

OPS: Office of Pipeline Safety (PHSMA)

PHMSA: Pipeline and Hazardous Materials Safety Administration

PISC: Post-injection site care

PSGC: Prairie State Generating Company

PRI: Prairie Research Institute

WGIII: Working Group III of the International Panel on Climate Change

WHEJAC: [White House Environmental Justice Advisory Council](#) 

USDW: Underground source of drinking water

UIC: Underground Injection Control (EPA program)

USACE: United States Army Corps of Engineers

U.S. EPA: United States Environmental Protection Agency

U.S. DOE: United States Department of Energy

USGS: United States Geological Survey

 **URL LINK**

A large, semi-transparent blue number '3' is positioned on the left side of the page, serving as a background element. The background is a bright blue sky with scattered white clouds.

EXECUTIVE SUMMARY

The Prairie Research Institute (PRI) is tasked with leading a Carbon Capture, Utilization, and Storage (CCUS) study group under [Public Act 102-0341](#) to assist the state of Illinois by providing objective, science-based research to help policymakers better understand the role that CCUS may play in meeting the state's emissions targets. PRI, part of the University of Illinois Urbana-Champaign, unites expertise in geoscience, ecology and environmental science, climate, sustainable energy, hydrology and water, archaeology, and pollution prevention.

An external advisory committee co-chaired by State Representative Ann Williams (11th District) and State Representative Tom Bennett (106th District) advised PRI on this report. Other members of the advisory committee were:

- Andrew Armstrong, chief, Environmental Bureau, Illinois Attorney General's Office
- Rob Baren, legislative liaison, Illinois Department of Agriculture
- Colleen Callahan, director, Illinois Department of Natural Resources
- Adnan G. Khayyat, chief, Division of Nuclear Safety and chief strategy officer, Illinois Emergency Management Agency
- Kyle Rominger, chief, Bureau of Land, Illinois Environmental Protection Agency
- Katherine Stonewater, senior advisor, Energy and Broadband, Illinois Department of Commerce and Economic Opportunity
- Illinois State Senator Craig Wilcox (32nd District)

This report discusses (1) the status of available carbon management technologies in Illinois; (2) opportunities for using or storing captured carbon dioxide (CO₂) underground; (3) key challenges that could affect the development, demonstration, and deployment of CCUS technologies; (4) stakeholder questions, concerns, and feedback; and (5) options that policymakers should consider to help address these challenges. It is worth noting that this report addresses all topics set forth by the statute requested by the Governor and Illinois General Assembly to the extent outlined in Public Act 102-0341. Any issues beyond the scope of this single report may be addressed in forthcoming reports from the state.


The CCUS study group conducted this work in accordance with all sections of [Public Act 102-0341](#):

- The current status and future storage resource potential in the state (Section 7).
- Procedures, standards, and safeguards for the storage of CO₂ (Section 7).
- Permitting processes and the coordination with applicable federal law or regulatory commissions, including the Class VI injection well permitting process (Sections 7–8).
- Economic impact, job creation, and job retention from carbon capture, utilization, and storage that both protect the environment and support short-term and long-term economic growth (Section 9).
- Development of knowledge capacity of appropriate agencies and stakeholders (Section 12).

- Environmental justice and stakeholder issues on carbon capture, utilization, and storage throughout the state (Section 12).
- Leveraging federal policies and public-private partnerships for research, design, and development to the state (Section 11).
- Liability for the storage and monitoring of CO₂ after the completion of a carbon capture, utilization, and storage project (Section 8).
- Acquisition, ownership, and amalgamation of pore space for carbon capture, utilization, and storage (Section 8).
- Methodologies to establish any necessary fees, costs, or offsets (Section 9).
- Any risks to health, safety, the environment, and property uses or values (Sections 7, 10, and 12).

Considerations and Recommendations

The CCUS study group conducted research in each of the above sections of the Public Act and identified the following recommendations:

- CCUS could play an important role in achieving the state's decarbonization goals and equitable clean energy workforce development as outlined in the [Climate and Equitable Jobs Act \(PA 102-0662\)](#) .
- A standing interagency planning and oversight committee should be established to consider CCUS activities in Illinois.
- CCUS should be both enabled and appropriately regulated to ensure long-term storage of CO₂ in full consultation with impacted communities to address community concerns.
- CCUS policies and projects should exceed regulated engagement requirements and include environmental justice considerations and broadly engage stakeholders.
- Public policies, investments, and other incentives or drivers for CCUS should complement renewable energy and other solutions that directly reduce emissions.
- CCUS should be deployed in ways that support new economic opportunities and build on existing economic strengths and infrastructure.

Infrastructure

U.S. Department of Energy (U.S. DOE)-funded Front-End Engineering and Design (FEED) capture studies and carbon storage studies conducted within the state have demonstrated that Illinois is a highly suitable location for CCUS as a carbon management technology. The following recommendations are based on study findings and broad stakeholder input regarding development of a CCUS industry within Illinois. Other states have addressed many of the issues listed below.

Capture and Utilization

- Consider developing mechanisms to collect and report data regarding the non-carbon dioxide air emissions associated with carbon capture projects.
- Examine the means to accelerate the permitting process required for deployment of capture systems, including permits for air, water, and wastewater.
- Create incentives for use of products that utilize captured CO₂. Related examples of this include the low carbon fuel standards credit (Low Carbon Fuel Standard, [California Air Resources Board](#)) established in California.
- Consider incentives that encourage the development or use of products with the best CO₂ benefits.
- Consider enhancing support and consistent funding of CCUS research and development and large-scale demonstrations simultaneously.

Transport

Public Act 102-0341 does not explicitly include the transport of CO₂, but issues of whether, how, and where CO₂ should be transported are inextricably linked to the overall feasibility of CCUS. It is important to note that transport was a significant concern of stakeholders.

- Retain experts who have specialized knowledge, skill, education, experience, and training in CO₂ transportation and pipelines to investigate further.
- Identify existing infrastructure rights-of-way and suitable locations for potential CO₂ pipeline corridors to facilitate future deployment.
- Develop a regional CO₂ transport infrastructure action plan with surrounding states or join existing initiatives.
- Consider establishing a state-level siting authority that appropriately addresses the concerns of local governmental bodies.
- Incorporate federal law and regulation for transportation of CO₂ for underground carbon storage into state law and empower the appropriate agency as a certified partner of the Pipeline and Hazardous Materials Safety Administration (PHMSA) to implement that law.

Storage

- Consider establishing a state-level oversight authority that appropriately addresses the concerns of local governmental bodies.
- Incorporate federal law and regulation for underground carbon storage into state law and empower the appropriate agency(ies) to coordinate carbon storage activities.
- Encourage direct coordination between federal, state, and local governments for permitting and regulating underground carbon storage locations and setting operational standards.

- Encourage the development of a clear process for state requirements and guidelines for siting, permitting, and oversight of carbon storage projects not already regulated by federal processes.
- Create legal and regulatory frameworks for the long-term (post-closure) stewardship and oversight of geologic storage sites.

SUBSURFACE RIGHTS

- Clarify pore space ownership for landowner protection and for the adoption and implementation of an effective CCUS program in Illinois.
- Review existing property law and consider the development of a mechanism to combine subsurface property interests to enable large-scale projects.

Permitting under UIC Class VI

- Create legal and regulatory frameworks for the long-term stewardship and oversight of geologic storage sites.
- Encourage interagency and stakeholder discussion to determine if the state of Illinois will seek Underground Injection Control (UIC) program primacy for the Class VI well class. If the state of Illinois considers seeking primacy for the UIC Class VI program:
 - Secure adequate staff and resources for all relevant state agencies to ensure sufficient expertise, knowledge, and personnel availability to process permit applications in a timely fashion and ensure the safe and effective regulation of carbon storage.
 - Examine opportunities to obtain dedicated external funding to support securing the required staff. Additional consideration should be given to securing devoted Class VI program funding recently made available to states through the passage of the [Infrastructure Investment and Jobs Act \(H.R. 3684\)](#).

Economic Considerations

- Retain experts who have specialized knowledge, skill, education, experience, or training in economics, finance, or tax law to:
 - Consider the use of fees to support scientific research that promotes safe, good stewardship through the life cycle of CCUS.
 - Consider the economic opportunities to offset the cost of CCUS by using CO₂ to produce additional benefits, such as through concrete, chemicals, fuels, and agricultural products.

Energy and Climate Policy

- Consider the adoption of greenhouse gas (GHG) accounting protocols for CCUS projects to appropriately assess progress made toward state climate targets. This should include a review of the approach to carbon accounting used by the U.S. Environmental Protection Agency and the IRS in connection with 45Q or 45Z tax credits and consideration of any modifications needed to reflect Illinois' needs.

Environmental Protections and Environmental Justice

Article XI of the Illinois Constitution [↗](#) establishes that a “healthful environment” is a fundamental right of all Illinois residents and that it is the public policy of Illinois to maintain a healthful environment for the benefit of current and future generations. To mitigate harms and prioritize benefits, it is important to identify where locations of CCUS might impact Illinois’ population, and especially affect areas of environmental justice concern, and to prioritize those community voices in decision-making.

- CCUS deployment should prioritize environmental health and equity in consideration of planned CCUS activities.
- Governments and industries should conduct consistent energy, water equity, and supply assessments to ensure environmental protections are in place to address any public health considerations and impacts to dependent flora and fauna.

Communication and Public Engagement

- Expand education and engagement for CCUS such that all stakeholders are better informed about safety, risks, benefits, planning, and management, particularly when plans are made, reviewed, and updated.

Stakeholder Engagement

In assembling this report, the CCUS study group reviewed an inventory of existing CCUS initiatives in the state and nationally; performed a literature review; compiled a review of the existing legislation to supplement the report; employed an outside firm, **Industrial Economics, Incorporated** [↗](#), to conduct an Impact Analysis for Planning (IMPLAN) economic impact analysis; and hosted 13 virtual stakeholder listening sessions, composed of the following groups:

- More than two dozen staff of state agencies with an interest in CCUS, including the Illinois Attorney General’s Office, Illinois Department of Agriculture, Illinois Department of Natural Resources, Illinois Emergency Management Agency, and Illinois Environmental Protection Agency;
- Environmental advocacy and environmental justice organizations, including the Illinois Environmental Council (IEC), which invited their affiliate member organizations and representatives from the Illinois Clean Jobs Coalition (invitations were sent to nearly 125 organizations);
- Farmers and the Illinois Farm Bureau;
- Boilermakers Local 60, Boilermakers Local 363, United Mine Workers of America District 12; and
- Businesses with an interest in managing their carbon emissions and those that provide carbon management services.

PRI also held virtual listening sessions open to the general public on Sept. 21, Sept. 22, and Oct. 3, 2022 and participated in a stakeholder meeting at the National Sequestration Education Center in Decatur, Illinois on May 17, 2022.

Stakeholders provided a diverse range of opinions. The following section details the concerns, questions, opinions, and feedback that were collected via virtual listening sessions and written comments provided either through the CCUS website or sent directly to the CCUS study team. Stakeholder opinions and objectives varied significantly and represented multiple perspectives—often resulting in opposing viewpoints. The intent of this section is to portray stakeholder comments as received.

THE FOLLOWING SECTION DOES NOT REFLECT THE VIEWS OF THE PRAIRIE RESEARCH INSTITUTE, THE UNIVERSITY OF ILLINOIS, OR THE STATE OF ILLINOIS. NAMES OF GROUPS, INDIVIDUALS, AND AGENCIES HAVE BEEN REDACTED TO PROTECT THE PRIVACY OF THE INDIVIDUAL OR ENTITY.

CO₂ Storage Safety and Risks

Stakeholders expressed concerns about whether geologic storage sites will leak, whether there will be groundwater safety concerns, and whether geologically storing CO₂ will cause earthquakes. These concerns have been discussed in the Carbon Storage section of this report. Several people in the environmental advocacy listening sessions asserted that Illinois should not assume liability for stored CO₂ from private companies or developers. In contrast, corporate commenters indicated that they would like to see ownership of closed CO₂ storage sites transferred to the state government for long-term stewardship.

Human Health and the Environment

Several stakeholders expressed concerns that power plants with CCUS units use more energy, thereby increasing emissions of pollutants other than CO₂ and negatively impacting the air quality of the surrounding communities, while perpetuating fossil fuel use. Some stakeholders said they were fully against any form of carbon capture and sequestration that perpetuates the use of fossil fuels in any way. Others were concerned that carbon capture does not remove other pollutants associated with coal-fired power plants and noted that the solvents typically used to capture CO₂ in flue gas must be captured as hazardous waste.

STAKEHOLDERS OPINION

The report will not go far enough to address safety and environmental risks.

Commenters also have concerns about the amount of water used by carbon capture projects and want water supply to be considered when evaluating the life cycle impact of CCUS projects. Some stakeholders asked, “Are there lessons to be learned from the wind industry about interacting with landowners?”

Various stakeholders suggested that the state should halt the transport or storage of CO₂ within state lines and direct more resources to accelerate the transition to renewable energy sources, such as wind, solar, and backup battery power. Other stakeholders favored alternative CO₂ mitigation strategies, including abandoning fossil fuels entirely in conjunction with planting native trees, restoring prairies, and protecting the rainforest.

Transportation and Pipelines

Stakeholders expressed concern that the Public Act did not include transportation within the scope of the study, and that the issue of CO₂ transportation in Illinois will not be given adequate attention by the State and could be misleading the public about the comprehensive risks of CCUS in Illinois. Furthermore, an “absence of the impacts and consequences of pipelines” lends itself to be a “major loophole within the study.”

STAKEHOLDERS OPINION

Pipelines are a major concern for landowners and are likely underrepresented in the study. Stakeholders cited disruption to farmland and other properties, energy used to transport, and the overall footprint of pipelines.

Carbon capture and storage will require a system of pipelines to transport the captured CO₂ to the sequestration site. Stakeholders inquired about the lifetime carbon footprint of CCUS technologies at an industrial scale, noting that the evaluation of all carbon capture and storage projects should include full accounts of:

- Pipeline construction, and the subsequent disruption to nearby farms, residential, and commercial properties.
- The manufacture of steel for the pipelines.
- The energy required to condense the CO₂ into a supercritical state and to pump it to its destination.
- The intensive monitoring and maintenance during the operational phase of the pipeline.
- Pipelines used to transport CO₂ for enhanced oil recovery (EOR) must include the eventual burning of the recovered oil.

Other stakeholders stated they believe that carbon capture and storage technologies pose an unnecessary safety threat to communities across Illinois from start to finish. As the CO₂ is transported in a high-pressure, supercritical liquid state, there is always a risk that the pipelines could be damaged.

Many stakeholders, especially agricultural stakeholders, are concerned about how deep pipelines should be buried. People expressed concerns about what happens if a pipeline is broken or leaks or both near a metropolitan area, and what happens if pipelines are sited too close to homes. Stakeholders are especially concerned about the impacts on the health of people living near pipelines and on their property values. Several people in the environmental advocacy listening

sessions urged decision-makers to consider the full life cycle impacts of pipelines and mentioned that they would like to see a moratorium on CO₂ pipelines until the Pipeline and Hazardous Materials Safety Administration (PHMSA) finalizes its regulations.

Property and Ownership

Stakeholders agreed that there is a need for the State to set clear guidelines regarding pore space ownership, access, and unitization, but held opposing viewpoints about those issues.

STAKEHOLDER OPINION: Carbon storage poses unnecessary and uncertain risks because pore space is not a defined area that can be controlled.

Property owners are concerned about forced amalgamation if more than 50 percent of people in a particular area agree to the development of a storage project incorporating pore space. They also expressed concern about the use of eminent domain for CO₂ storage projects. The rapid development of energy and CO₂ storage projects has caught landowners by surprise, and some are reporting project fatigue due to the number of inquiries to use their land. Landowners also have questions about who owns pore space and how surface rights relate to subsurface rights. Property concerns related to pipeline siting are detailed in the relevant sections of this report.

STAKEHOLDER OPINION: Illinois should consider clarifying pore space ownership where the surface and mineral estates have been split, which is essential for advancing CCUS projects. Illinois should set clear guidelines that allow for CCUS project development if a majority of owners of a block of land agree.

Some stakeholders suggested looking to other states' frameworks for guidance. Several states have enacted pore space ownership and use legislation, and the majority have determined that pore space ownership is vested with the surface owner.

Stakeholders also expressed the following opinions regarding pore space ownership, access, and management:

Pore space access: Ensuring there are clear mechanisms to allow for the various State-owned lands and pore space to be accessed for carbon storage will be critical to ensuring the storage potential of Illinois is fully realized.

Mechanism to enable unitization of pore space: The ability to aggregate and unitize pore space is one of the most important factors to enable at-scale CCS business development. A 60% threshold for pore space unitization is consistent with legislation passed by other states. Unitization is particularly important for Illinois, considering the regulatory certainty in neighboring states and the size of the projected CCS market.

Post-injection transfer of ownership, management, and responsibility: Illinois may develop a legal framework for the state to accept a transfer of ownership, management, and responsibility for the CO₂ and

storage facility after secure geologic storage is demonstrated. Several states such as Indiana, Louisiana, and North Dakota have enacted legislation to address this issue.

Economic Impact

Stakeholders expressed conflicting viewpoints regarding the economic impacts of CCUS.

Some stakeholders said CCUS can provide a positive economic impact in Illinois and position businesses in Illinois to be globally competitive as the energy economy shifts towards low- and zero-carbon energy sources.

However, other stakeholders argue that CCUS is a questionable technology and an expensive endeavor and that public funding should be used to fund education and address public infrastructures, such as hospitals, roads, and maintenance of municipal buildings.

Permitting

While permitting clarity within the state is needed, stakeholders had varying perspectives about primacy at the state level. The CCUS study group section is designed to ensure that a broad spectrum of stakeholder opinions is shared with the State.

STAKEHOLDER OPINION: Federal regulatory processes are sufficient to address CCUS permitting needs.

Some stakeholders did not support the creation of a new regulatory or permitting scheme in Illinois, citing the U.S. EPA's Underground Injection Control requirements for Class VI injection wells are comprehensive as far as procedures, standards, and safeguards, especially with regards to well construction, characterization, modeling, monitoring, safety, prevention of leakage, and financial assurance. Additionally, stakeholders expressed concerns that creating an entirely new state-based permitting and regulatory scheme could impede the development of CCUS in Illinois.

“The federal Class VI permitting process is sufficient. Delaying the ability to sequester CO₂ by recommending additional and potentially contradictory permitting and/or approvals by State agencies would negatively impact the project timeline and the environmental benefits that could be achieved.”

STAKEHOLDER OPINION: Illinois should consider applying for primacy over the Class VI permitting program, but only if the State can design and implement a process that grants a Class VI permit within a shorter timeframe relative to U.S. EPA while delivering an equal assurance of safety and operational integrity.

Some stakeholders said that state primacy has given other states, such as North Dakota, a competitive advantage by having the ability to move promptly on permitting and issuing its first Class VI permits. Many industrial stakeholders emphasized that establishing predictable permitting timelines would have a significant positive impact on business development in Illinois.

STAKEHOLDERS OPINION

Public funding should not be used for supporting this suite of technologies and could be better used on schools and public buildings.

STAKEHOLDERS OPINION

Illinois may find itself a less attractive investment option when other states have more flexible policies.

Technology Readiness

Stakeholders held conflicting viewpoints over the proven effectiveness and readiness level of CCUS technology to mitigate the impacts of climate change.

STAKEHOLDER OPINION: Carbon Capture and Storage (CCS) is expensive, non-effective technology, and is not proven.

Many stakeholders shared opinions that carbon capture and storage is both expensive and ineffective for reducing greenhouse gas emissions and when used for enhanced oil recovery (EOR), carbon capture adds more CO₂ to the atmosphere than it removes. Further comments included concerns that CCUS technologies do not reduce methane (CH₄), nitrous oxide (NO₂), perfluorocarbons (PFCs), sulfur hexachloride (SF₆), and nitrogen trifluoride (NF₃).

Other stakeholders stated they were concerned about the safety threat from the high-pressure, supercritical liquid of CO₂ that is proposed to be transported through communities.

Various stakeholders recommended increasing support for renewable energies such as wind, solar, and geothermal to help reduce greenhouse gas (GHG) emissions.

Conclusion

CCUS could play a critical role in combating climate change and decarbonizing the global economy. However, deploying CCUS at a larger scale in Illinois will require robust governance to ensure these systems are delivering desired societal outcomes and have broad and deep public support.

The state is particularly focused on the role that CCUS could play in maintaining and creating well-paying union jobs and addressing cumulative impacts in historically disadvantaged communities, which is addressed in detail in the Economic Impact section of this report. Incentives, structures, and policies, such as the Section 45Q tax credit, California's Low Carbon Fuel Standard, and the U.S. Department of Energy's RDD&D funding opportunities, are likely to accelerate CCUS deployment. At the federal level, the U.S. Environmental Protection Agency (EPA) has a regulatory framework under the Safe Drinking Water Act and the Clean Air Act that ensures the long-term, safe, and secure geologic sequestration of CO₂. Still, federal regulations and incentives alone are not enough for successful and responsible technological deployment and must work in tandem with the creation of policies that provide clarification in areas of transport, ownership, permitting, and safeguarding public health and the environment.

CARBON DIOXIDE PIPELINES ARE CRITICAL COMPONENTS TO THE STATEWIDE DEPLOYMENT OF CCUS, AND MORE EXTENSIVE RESEARCH IS NEEDED TO IDENTIFY POSSIBLE PATHWAYS AND INFRASTRUCTURE NECESSARY TO ACHIEVE ECONOMICAL CCUS AT AN INDUSTRIAL SCALE IN ILLINOIS.

Significant investments, planning, and community engagement and analysis will be required. The scale of implementation of CCUS and transport is likely needed to achieve the state's climate goals may raise concerns about public health and environmental impacts and questions about who stands to benefit from the deployment of these systems.

Responsible CCUS projects should follow best practices and address societal considerations. CCUS will only deliver desired societal and environmental benefits if its deployment is well-designed and well-governed.



INTRODUCTION



There is broad consensus in the scientific community that the need to address climate change is urgent; that it cannot be adequately addressed without using a combination of adaptive strategies (e.g., lifestyle changes such as reducing fossil fuel use) and mitigative strategies (e.g., large-scale carbon capture, use, and storage coupled with renewable energy technologies); and, importantly, that such strategies are not mutually exclusive choices (Medvecky et al., 2014). Reports from the [Intergovernmental Panel on Climate Change](#) (IPCC), White House Committee on Environmental Quality (CEQ), and National Academies of Science all indicate that capturing, using, and storing carbon dioxide (CO₂) are among the strategies needed to reach national and global climate goals.

The Prairie Research Institute (PRI) was tasked with leading a Carbon Capture, Utilization, and Storage (CCUS) study group under [Public Act 102-0341](#) to assist the state in providing objective, science-based research on CCUS technologies. This report discusses: (1) the status of available carbon management technologies in Illinois; (2) opportunities for using or storing captured CO₂; (3) key challenges that could affect the development, demonstration, and deployment of CCUS technologies; and (4) options that policymakers should consider to help address these challenges. In compiling this report, PRI conducted a literature review, held 13 virtual stakeholder listening sessions, and employed an outside firm, [Industrial Economics, Incorporated](#), to conduct an Impact Analysis for Planning (IMPLAN) economic impact analysis. PRI has outlined and addressed various stakeholder issues and perspectives within this report.

Examples of CCUS technology include post-combustion chemical absorption of CO₂ or construction of CO₂ pipelines and other CCUS-supportive infrastructure.

KEY PRIORITIES FOR CCUS ARE IMPROVING EFFICIENCY, ECONOMIC VIABILITY, AND SAFETY. IMPROVEMENTS OF CATALYSTS AND PROCESS DESIGNS ARE CRITICAL TO LOWER COSTS, MATERIAL CONSUMPTION, AND WASTE PRODUCTION, AND TO INCREASE EFFICIENCY.

[Public Act 102-0662](#), commonly known as the Climate and Equitable Jobs Act (CEJA), was signed by Governor Pritzker on September 15, 2021. This legislation takes many important steps to fight climate change by decarbonizing the state's energy sector, investing in clean and renewable energy sources, promoting the adoption of electric vehicles, centering equity, as well as developing the workforce across Illinois. The act mandates various actions to implement new programs, initiatives, and directives to further the state's goals of transitioning to 100 percent clean energy, supporting a transition away from carbon-intensive power generation, increasing public participation in regulatory matters, and encouraging further diversity and inclusion within the renewable energy industry.

CCUS refers to a group of technologies for reducing CO₂ emissions or removing CO₂ from the atmosphere. *Capture* includes technologies that separate CO₂ from a large emission source, such as a power generation industrial facility or cement manufacturing facility (*point source capture*), or directly from the ambient atmosphere (*direct air capture*). Both CO₂ captured via point source capture or direct air capture can be compressed and transported—via truck, air, railcar, or pipeline—either for conversion into economically valuable products (*utilization*) or for long-term *storage* in deep underground geologic formations.

These technologies are proven to reduce CO₂ emissions or remove CO₂ from the atmosphere, and they could preserve existing jobs as well as create new ones and enhance the ability of U.S. companies to sell or export low-carbon products or CCUS technologies as more businesses and nations set greenhouse gas (GHG) reduction goals.

According to the U.S. Environmental Protection Agency (EPA) [↗](#), CO₂ emissions made up 79 percent of all GHG emissions in 2020, followed by methane (11%), nitrous oxide (7%), and fluorinated gases (3%). Climate change results from GHGs that trap heat by absorbing energy from the infrared radiation emitted by the Earth. This heat-trapping effect, the “greenhouse effect,” causes atmospheric

FIGURE 1. Carbon capture, utilization, and storage (CCUS) refers to a set of technologies that remove carbon dioxide (CO₂) from the emissions of point sources or the atmosphere, and compress gas to a liquid and either transport it or inject it deep beneath the earth’s surface and monitor sites to verify safe and secure storage operations. Carbon dioxide can also be transformed by utilizing it in industrial processes.

POINT SOURCES

which can include power plants, ethanol plants, cement plants, & other industrial facilities

CARBON CAPTURE

CO₂ captured from exhaust or directly from the air is diverted for

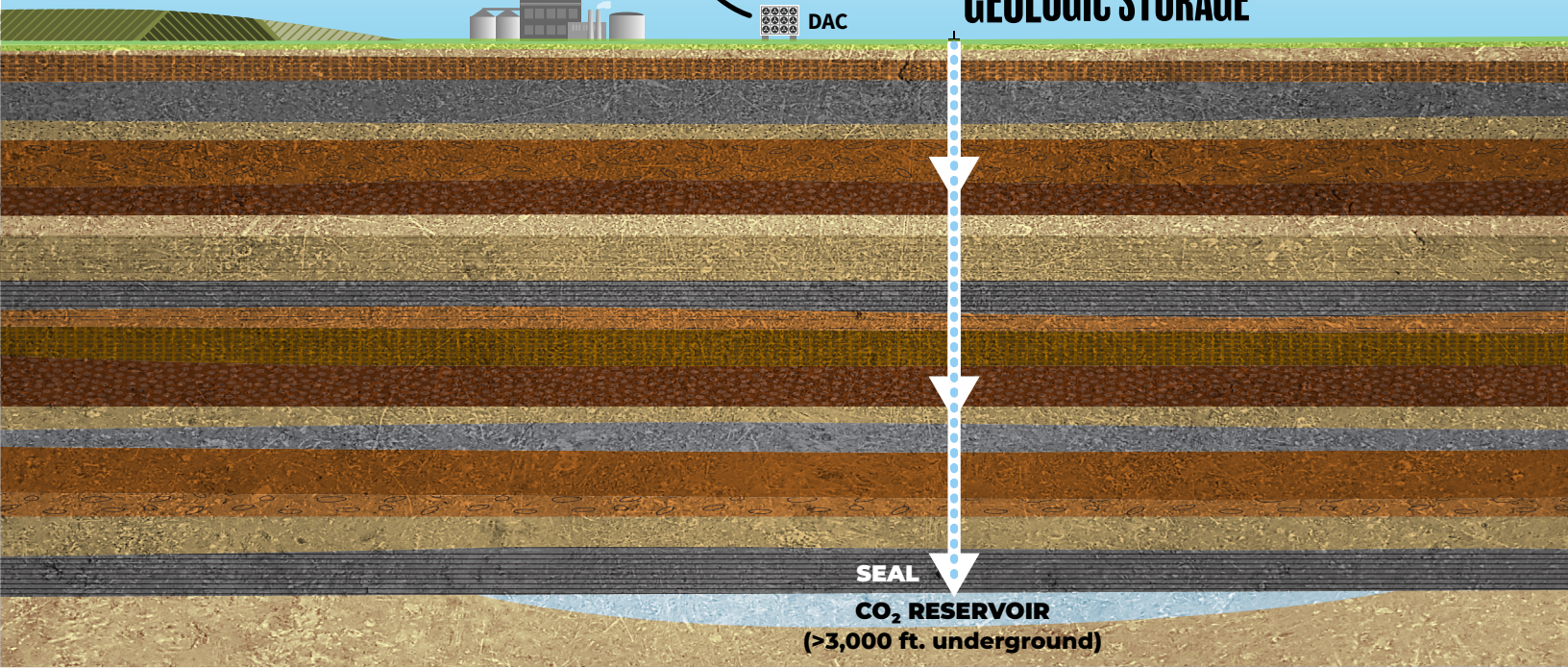
UTILIZATION

GEOLOGIC STORAGE

DAC

SEAL

CO₂ RESERVOIR
(>3,000 ft. underground)



warming, resulting in changes to the climate, including more frequent and intense extreme weather events felt around the world.

IN THE UNITED STATES, CARBON CAPTURED FROM INDUSTRIAL SOURCES HAS BEEN A PRIMARY FOCUS BY RETROFITTING EXISTING POWER PLANTS WITH VARIOUS CARBON CAPTURE TECHNOLOGIES.

STAKEHOLDERS ASKED

How many CCUS locations will there be? Could they be in every county?

Combined with carbon storage techniques, which are source agnostic, the ability to capture concentrated sources of GHG emissions before entering the atmosphere can help align future CO₂ emissions from the power sector with pathways to limit warming to 2°C or lower. Illinois' geology is particularly suitable for carbon storage. More than a mile underground is the Mt. Simon Sandstone, which is a primary target for geologic storage of CO₂, not only because of its suitability for storage but also its distance from groundwater aquifers, fossil fuels, and the low number of wells drilled into the sandstone. The Eau Claire Shale, an impermeable rock unit, overlies the Mt. Simon Sandstone and acts as a barrier to upward CO₂ movement.

STAKEHOLDERS ASKED

What utilization options are under consideration?

Carbon utilization refers to the ways that captured carbon oxides, principally CO₂, can be used to produce economically valuable products or services. Carbon utilization is generally applicable to any flue gas stream generated by the combustion of carbon-based fuels, such as coal, natural gas, and biomass, as well as several other carbon-rich waste gas streams that are currently vented to the atmosphere. The development of technologies that lead to revenue-generating products can help support broader carbon emissions reduction strategies. Carbon dioxide can be used in multiple ways to produce economically valuable products and services by several pathways, according to the U.S. Department of Energy (U.S. DOE) Office of Fossil Energy and Carbon Management (FECM). The emerging field of CO₂ utilization encompasses many possible products and applications: fuels, organic and inorganic chemicals, food and feeds, construction materials, enhanced resource recovery (e.g., oil, gas, water, and geothermal energy), energy storage, wastewater treatment, and others.

For storage, CO₂ is compressed into a liquid and injected through an isolated well deeper than 3,000 feet into a sandstone that is both porous and permeable with a good sealing unit above it. This package of rocks, a storage formation, and a seal formation is known as a storage complex. As the CO₂ is injected into the sandstone formation, it enters the pore space, some dissolving partly into the naturally occurring brines where it will be contained permanently, and some remaining in a liquid state in the pore space.

MONITORING THE STORED CO₂ IS CRITICAL FOR ENSURING SAFE AND EFFECTIVE STORAGE.

STAKEHOLDERS ASKED

How do you keep CO₂ from migrating between different pore space?

Stakeholders often express concern about the safety of groundwater, whether geologic storage sites will leak, or whether geologically storing CO₂ will cause earthquakes. Monitoring wells are specifically drilled for carbon storage to measure temperature, pressure, and acoustics and to make sure that these wells are constructed at the very highest level and adhere to strict guidelines. All carbon capture and storage projects should undergo rigorous risk assessments that include characterizing the site by evaluating its geology to assess its suitability for storage, operating the site while CO₂ is being injected deep underground, and through the federally mandated post-injection site care (PISC) period, typically 50 years after injection has ended.

CCUS LAWS AND REGULATIONS MUST ALSO ENSURE THE PROTECTION OF THE ENVIRONMENT AND PUBLIC HEALTH, CLARIFY THE RIGHTS AND RESPONSIBILITIES OF STAKEHOLDERS, AND PROVIDE A LEGAL FOUNDATION FOR THE DEVELOPMENT, OPERATION, AND LONG-TERM MANAGEMENT OF CO₂ STORAGE RESOURCES.

Illinois has *not* explicitly addressed ownership and control of pore space in Illinois through legislation. Carbon storage operators and landowners alike have sought clarification as to what laws or regulations exist in Illinois regarding the integration of pore space. Although Illinois has not explicitly addressed this question with respect to CCUS, the [Illinois Oil and Gas Act](#) (225 ILCS 725) and its implementing regulations address similar questions regarding oil and gas rights. Recent legislation from Indiana, Louisiana, Montana, North Dakota, Utah, West Virginia, and Wyoming can provide insights into ways in which this issue has been addressed (see the [CCUS Law and Policy Supplement](#) for details on these state laws).

THERE IS NO CURRENT ILLINOIS LEGISLATION OR CASE LAW THAT EXPLICITLY ADDRESSES LONG-TERM RESPONSIBILITY FOR CARBON STORAGE SITES IN ILLINOIS.

STAKEHOLDERS ASKED

Is there a threat or hazard related to CO₂ storage? Who should someone call if something happens?

As part of the federal permitting process for Class VI carbon storage wells, operators are required to demonstrate financial assurance that they have sufficient financial resources in the form of qualifying third-party instruments or self-insurance to carry out geologic storage activities, including all required monitoring, site closure activities, any

necessary remediation, and post-injection site care, which by default is 50 years after injection concludes (U.S. EPA, 2011). These requirements are intended to prevent the public from bearing the costs of abandoned geologic storage projects. Louisiana, North Dakota, and Texas all have laws that transfer responsibility for carbon storage sites to the state after a specified time or after specific conditions have been met, or both, while Kansas law expressly rejects state responsibility for carbon storage (see the [CCUS Law and Policy Supplement](#) for details on these state laws).

The following report is structured thematically across the following eight sections:

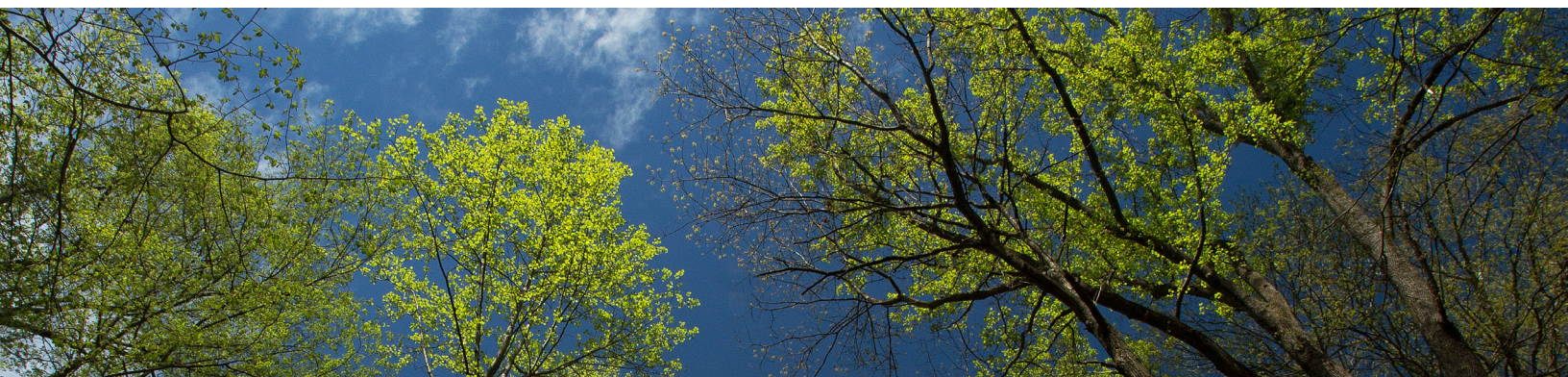
5. Carbon capture
6. Carbon utilization
7. Carbon storage
8. Policy considerations in Illinois
9. Economic impact
10. Transport of CO₂
11. Federal policies and public-private partnerships potential
12. Stakeholder engagement and environmental justice

Sections 5-7 examine and explain existing CCUS technologies and the current capabilities of the CCUS landscape in Illinois. Additionally, these sections look ahead to research development challenges and opportunities surrounding carbon capture, utilization, and storage at the federal and state level.

Sections 8-11 identify and articulate complex economic and policy considerations for legislators to address. A separate law and policy supplement accompanies this report to aid in addressing these sections specifically.

Section 12 comprises stakeholder and environmental justice concerns to be considered for the successful widescale deployment of CCUS activities in Illinois. The stakeholder feedback was collected from virtual listening sessions and written submissions [via the CCUS website](#).

Stakeholder concerns generally fell into the following categories: public engagement; economic impacts; pipeline siting and safety; pore space ownership, access, and unitization; permitting; climate change impacts; and other risks such as groundwater contamination, seismicity (earthquakes), CO₂ leakage, and property devaluation. Stakeholder engagement is a critical component of this report, as well as the successful deployment of CCUS in Illinois.



CARBON CAPTURE

This section outlines two major types of carbon capture technologies, addresses challenges and opportunities for technology development, and details a list of ongoing carbon capture projects in Illinois.

PUBLIC ACT 102-0341

Carbon capture, utilization, and storage current status and future storage resource potential in the state. Enhanced Oil Recovery shall remain outside the scope of HB0165
Enrolled LRB102 03889 SPS 13904 b
Public Act 102-0341 [this study]

STAKEHOLDERS ASKED

How does carbon dioxide capture from smokestacks make a difference in fighting the climate crisis?

The latest International Panel on Climate Change (IPCC) report revealed that CO₂ emissions from fossil fuel combustion and industry comprise 64 percent of total global greenhouse gas emissions (IPCC Working Group III, 2022). In the United States, carbon captured from point sources has been a major focus. Capture at these point sources prevents new CO₂ from entering the atmosphere. Point sources are defined as power generation or industrial facilities that emit CO₂. Industrial facilities include, but are not limited to, ethanol plants, cement plants, iron and steel manufacturers, chemical plants, oil refineries, natural gas processing facilities, and pulp and paper processing facilities. These facilities are typically retrofitted with a capture system to separate out the CO₂ and prevent it from being emitted to the atmosphere. The captured CO₂ is in such large volumes that most will need to be geologically stored.

COMBINED WITH CARBON STORAGE TECHNIQUES, WHICH ARE SOURCE AGNOSTIC, THE CARBON CAPTURE TECHNOLOGIES CAN HELP ALIGN FUTURE CO₂ EMISSIONS FROM THE POWER SECTOR WITH PATHWAYS TO LIMIT GLOBAL WARMING TO 2°C OR LOWER.

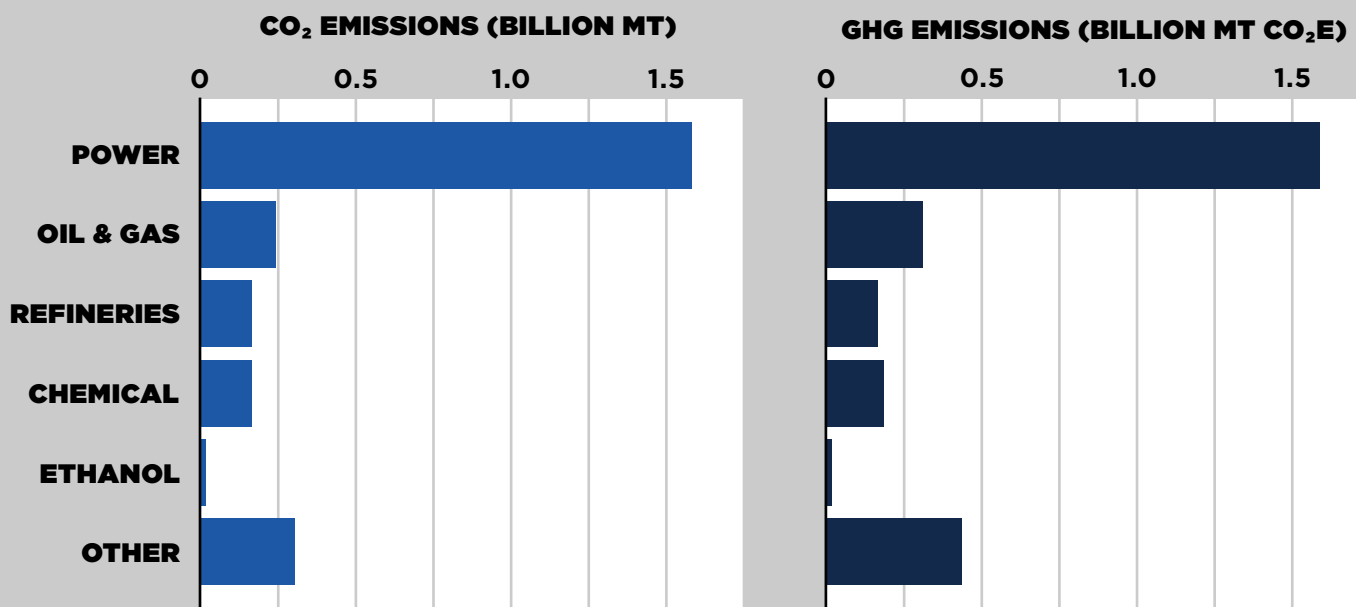


FIGURE 2. This figure from the U.S. EPA (2021) shows carbon dioxide (CO₂) emissions and total greenhouse gas (GHG) emissions by sector in billion metric tons (MT) and billion metric tons CO₂ equivalent (MT CO₂e). “Other” sectors include manufacturing processes such as minerals, waste, metals, pulp and paper, and food. Carbon dioxide (CO₂) enters the atmosphere largely via human activities such as burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., manufacture of cement). That’s why CO₂ is a prime target of our focus in this report and among emission reduction efforts to meet such global goals as Net Zero emissions by 2035. Net Zero means cutting GHG emissions to as close to zero as possible, with any remaining emissions to be reabsorbed from the atmosphere manually using capture techniques, or naturally by oceans and forests.

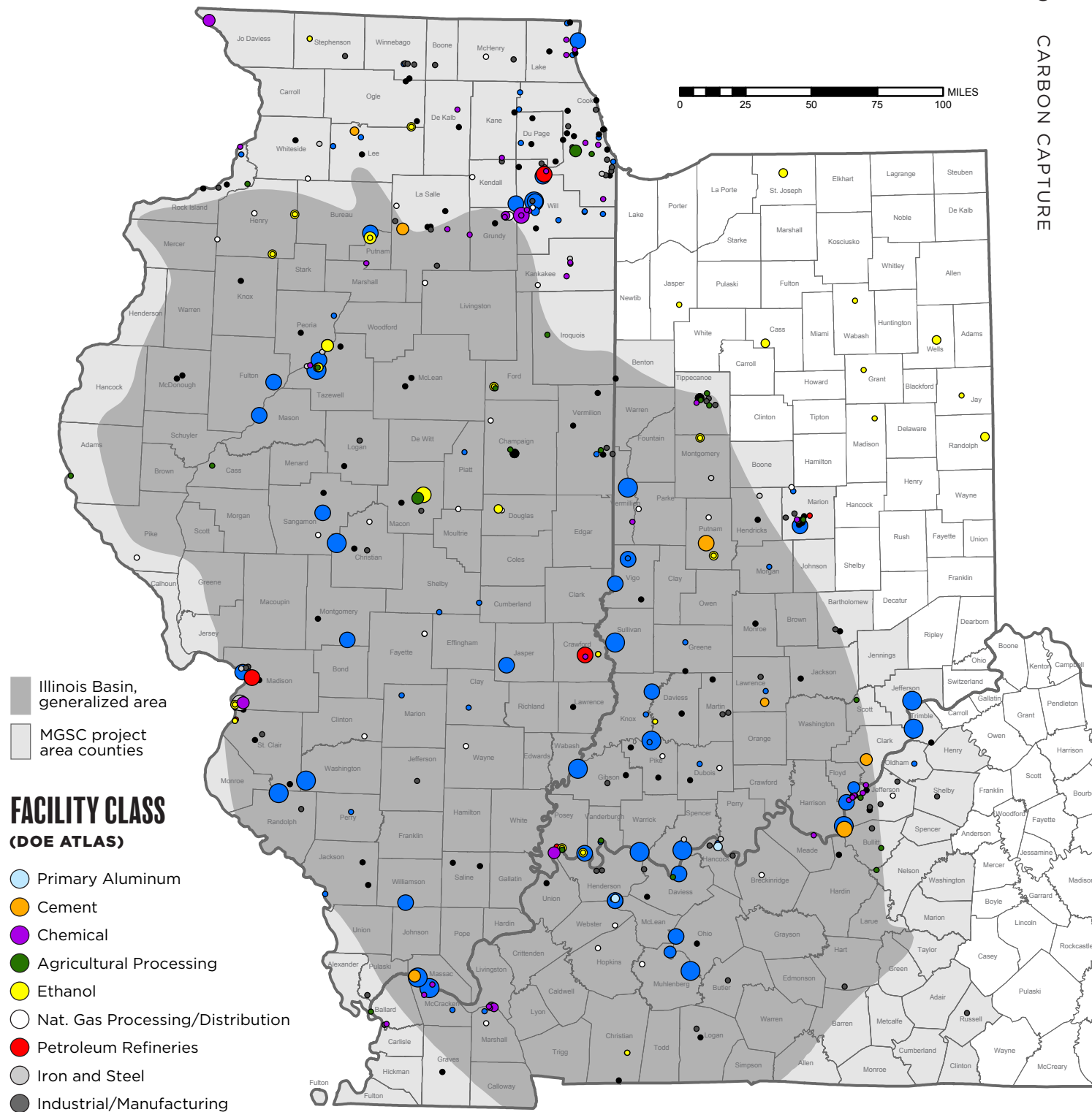


FIGURE 3. This figure illustrates point source carbon dioxide (CO₂) emissions locations across the Illinois Basin. It should be noted that CO₂ emissions vary from year to year. For example, factors impacting U.S. CO₂ emissions in the last few years include COVID-19 and the associated decline in economic activity, the retirement of coal-fired power plants and decline in coal use in favor of natural gas, investor concerns about the future of coal, the increasing use of wind power and other renewables, and geopolitical situations causing large changes in energy prices. **MGSC = Midwest Geological Sequestration Consortium. GHGRP = U.S. EPA Greenhouse Gas Reporting Program.**

FACILITY CLASS (DOE ATLAS)

- Primary Aluminum
- Cement
- Chemical
- Agricultural Processing
- Ethanol
- Nat. Gas Processing/Distribution
- Petroleum Refineries
- Iron and Steel
- Industrial/Manufacturing
- Other
- Electricity Generation

CO₂ TONNES (2015 EPA GHGRP)

- 10,000-250,000
- 250,001-500,000
- 500,001-1,000,000
- 1,000,001-5,000,000
- > 5,000,000

STAKEHOLDERS ASKED

What CO₂ sources are suitable for each capture technology or strategy?

The carbon capture process isolates CO₂ from the atmosphere and separates it from other gases through two types of sources: point source and direct air capture. Point source capture targets CO₂ from a large emission source (e.g., industrial facilities). Direct air capture (DAC) directly removes **existing CO₂** emissions in the atmosphere that were emitted from a variety of sources (e.g., automobiles, airplanes, boats). Both methodologies must be used in tandem to mitigate greenhouse gas emissions because a single methodology alone is not sufficient.

Point Source Capture

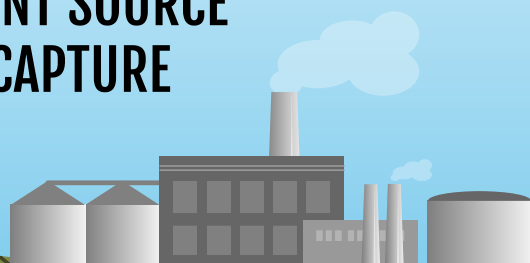
The U.S. Department of Energy (U.S. DOE) has established a methodology to systematically mature carbon capture technologies from the lab-scale to engineering scale to large pilot scale, and finally to the demonstration scale, to address the development of cost-effective and efficient capture technologies through its Office of Fossil Energy and Carbon Management (FECM).

Before carbon capture technology can be deployed, it must first start with a front-end engineering and design (FEED) study, outlining the blueprint of the proposed system. Beyond the FEED study, the technologies must be built at a facility and are then typically operated for one year or longer to assess cost efficiency and effectiveness.

The capture step is the costliest step of the CCUS process. Thus, a great deal of research is needed to develop technologies that reduce the cost of capture. For example, in Illinois such research and development has been carried out by the Illinois Sustainability Technology Center (ISTC) within the Prairie Research Institute (PRI). New point source capture technologies and consultations with other organizations are needed to evaluate and identify capture technologies that will suit the needs for power generation or industrial plants.

FIGURE 4. The two main types of carbon capture technologies are point source capture and Direct Air Capture (DAC). DAC can capture industrial-scale quantities of ambient carbon dioxide (CO₂) from the atmosphere, as opposed to point source capture, which is much more concentrated on a single location. Currently, DAC is more energy-intensive and more expensive than point source capture technologies.

POINT SOURCE CAPTURE



DIRECT AIR CAPTURE (DAC)



STAKEHOLDERS ASKED

What are the risks for carbon capture?

Carbon capture can also be a very water-intensive process. Therefore, when ISTC launched a FEED study for the largest post-combustion carbon capture system at the Prairie State Generating Company's (PSGC) Energy Campus in Marissa, Illinois, understanding impacts to water supply and identifying sustainable sources of water were a research priority. Requiring approximately 14 million gallons of water per day (MGD) at the time of initial setup, PSGC sources its water from one of the largest rivers in Illinois, the Kaskaskia River system, which includes Lake Shelbyville and Carlyle Lake.

As part of the FEED study, the [Illinois State Water Survey](#) (ISWS) at the Prairie Research Institute conducted a water availability analysis using streamflow frequency analysis and yield analysis to understand future impacts of climate change, such as severe droughts. ISWS combined a hydrologic model with climate model outputs to look ahead to 2100, making PSGC one of the first large-scale projects to explicitly address carbon capture and water supply issues together. The ISWS recommended using a storage pond to collect excess water during the wet seasons and to provide a backup water supply when streamflow in the Kaskaskia River is too low to supply water to the carbon capture system. Based on the ISWS analysis, the storage pond should be able to store enough water to meet the needs of the carbon capture system for 26 days. These types of studies are important for the state of Illinois in managing natural resources.

THE FOLLOWING PORTFOLIO OF PROJECTS HAS ENABLED ILLINOIS TO BE A WORLD LEADER IN CARBON CAPTURE RESEARCH AND DEVELOPMENT.

ABBOTT POWER PLANT. ISTC has partnered with the University of Illinois to test two different types of capture at the Abbott Power Plant, a cogeneration facility that simultaneously produces both steam and electricity to meet 70–75 percent of the Urbana campus' energy needs. ISTC led a U.S. DOE National Energy Technology Laboratory (NETL)-supported project to evaluate [an innovative biphasic solvent system](#) for its efficiency and effectiveness in absorbing CO₂ from flue gas at Abbott. The system was designed based on the testing results at the laboratory scale under a previous U.S. DOE cooperative agreement. The second project is [based on a mixed-salt carbon capture technology](#) developed by SRI International. This technology is being tested at the engineering scale at Abbott in a 0.5 megawatt electric (MWe) equivalent pilot campaign.

CITY WATER, LIGHT & POWER (CWLP). ISTC was selected to lead a U.S. DOE NETL- supported large-scale pilot testing of a Linde-BASF [CO₂ solvent-based carbon capture technology](#) at CWLP in Springfield, Illinois. When the 10-megawatt capture system is built and begins to process 5 percent of the Dallman Unit 4 flue gas, it will capture more than 90 percent of those CO₂ emissions. A second project aims to design [a next-generation power plant at CWLP](#) that both reduces emissions and captures and uses CO₂.

PRAIRIE STATE GENERATING COMPANY (PSGC). At 816 megawatts, PSGC is home to the largest carbon capture [FEED study](#) in the world, supported by the U.S. DOE, with a solvent-based post-combustion carbon capture technology from Mitsubishi Heavy Industries. The PSGC system is projected to be capable of capturing 8.5 million tons of CO₂ each year.

HOLCIM'S STE. GENEVIEVE CEMENT PLANT. A U.S. DOE-funded [FEED study](#) for a commercial-scale carbon capture retrofit of Holcim's Ste. Genevieve Cement Plant in Bloomsdale, Missouri is focusing on Air Liquide's Cryocap™ FG system for carbon capture.

Direct Air Capture

A major difference between direct air capture (DAC) and point source capture is that the volume of CO₂ captured by DAC tends to be much lower than that from point source capture. However, captured CO₂ by either technology can be combined and stored together.

COMPARED TO POINT SOURCE CAPTURE, DAC IS A RELATIVELY NEW CARBON CAPTURE TECHNOLOGY THAT REQUIRES DEVELOPMENT AND MATURATION.

Ongoing research focuses on evaluating DAC systems driven by renewable energy sources (wind, solar, and geothermal) combined with systems with excess heat from nuclear and industrial plants. The investment in developing and deploying DAC is growing (Budinis, 2022). As part of the Inflation Reduction Act of 2022, funding will be available through the U.S. DOE for the formation of DAC systems throughout the United States.


ILLINOIS CAN REALIZE ECONOMIC AND RESEARCH OPPORTUNITIES BY SEEKING FEDERAL FUNDING TO ESTABLISH A DAC HUB WITHIN THE STATE.

A brief outline of these projects is shown below.

STAKEHOLDERS ASKED

Does carbon capture decrease any of the greenhouse gases that are already in the atmosphere?

CLIMEWORKS. ISTC is developing preliminary designs for [the first commercial-scale DAC and storage system for CO₂ removal in the United States](#). This 18-month project will explore the feasibility of extracting 100,000 tons of CO₂ from the air annually, using technologies from the Swiss company Climeworks, which has built and operated several DAC plants in various climates across Europe. The team will test the large-scale DAC systems at three sites across the U.S. to assess how different climate conditions impact the process.

GARY WORKS PLANT. A FEED study of DAC technology developed by Carbon Capture Inc. at [U. S. Steel's Gary Works Plant in Gary, Indiana](#)  incorporates the use of the captured CO₂ at a nearby Ozinga ready-mix concrete plant. This U.S. DOE-supported project injects the CO₂ into concrete as it is being mixed, which causes the CO₂ to mineralize, locking it in the concrete and preventing it from returning to the atmosphere.

CONSTELLATION ENERGY'S BYRON NUCLEAR ENERGY PLANT. This project explores the benefits of constructing DAC technology at Constellation Energy's Byron nuclear energy plant in northern Illinois. Although nuclear plants do not produce carbon emissions, the plant can provide energy to power the DAC system, which could capture 250,000 tons of CO₂ each year.

The need and ability to leverage utilization and storage infrastructure for point source capture and DAC has given rise to the idea of forming CCUS hubs.

ILLINOIS IS WELL POSITIONED TO HOST A CCUS HUB, WHICH MIGHT INCLUDE MULTIPLE ENERGY TECHNOLOGIES THAT ARE CO-LOCATED WITH THE OBJECTIVE OF PRODUCING A DECARBONIZED ECONOMY.

RECOMMENDATIONS

- Consider developing mechanisms to collect and report data regarding the non-carbon dioxide emissions associated with carbon capture projects.
- Examine the means to accelerate the permitting process required for deployment of capture systems, including permits for air, water, wastewater, and so forth.
- Consider enhancing support and consistent funding of CCUS research and development and large-scale demonstrations simultaneously.

CARBON UTILIZATION

This section addresses the main carbon utilization technologies currently in effect in Illinois, new technologies that are being developed, and funding opportunities with universities, national laboratories, industries, and regional partners to advance technologies for carbon utilization projects.

PUBLIC ACT 102-0341

Carbon capture, utilization, and storage current status and future storage resource potential in the state. Enhanced Oil Recovery shall remain outside the scope of HB0165
Enrolled LRB102 03889 SPS 13904 b
Public Act 102-0341

Carbon utilization refers to the ways that captured carbon oxides, principally CO₂, can be used to produce economically valuable products or services. Carbon utilization is generally applicable to any flue gas stream generated by the combustion of carbon-based fuels, such as coal, natural gas, and biomass, as well as several other carbon-rich waste gas streams that are currently vented to the atmosphere. The development of technologies that lead to revenue-generating products can help support broader carbon emissions reduction strategies.

STAKEHOLDERS ASKED

Are we working to utilize CO₂?

Carbon dioxide is used directly within some industrial processes (e.g., enhanced oil recovery and for carbonation by the food and beverage industry) and is also converted into an array of other products. Overall, several carbon utilization technologies are still in the early stages of development, and the technology landscape is continually evolving.

ENHANCED OIL RECOVERY IS THE PRIMARY USE FOR CO₂, BUT IT IS OUTSIDE THE SCOPE OF THIS REPORT.

The three main utilization technologies for CO₂ in Illinois presently are algae, cement, and specialty chemicals. Select works occurring in Illinois are outlined below.

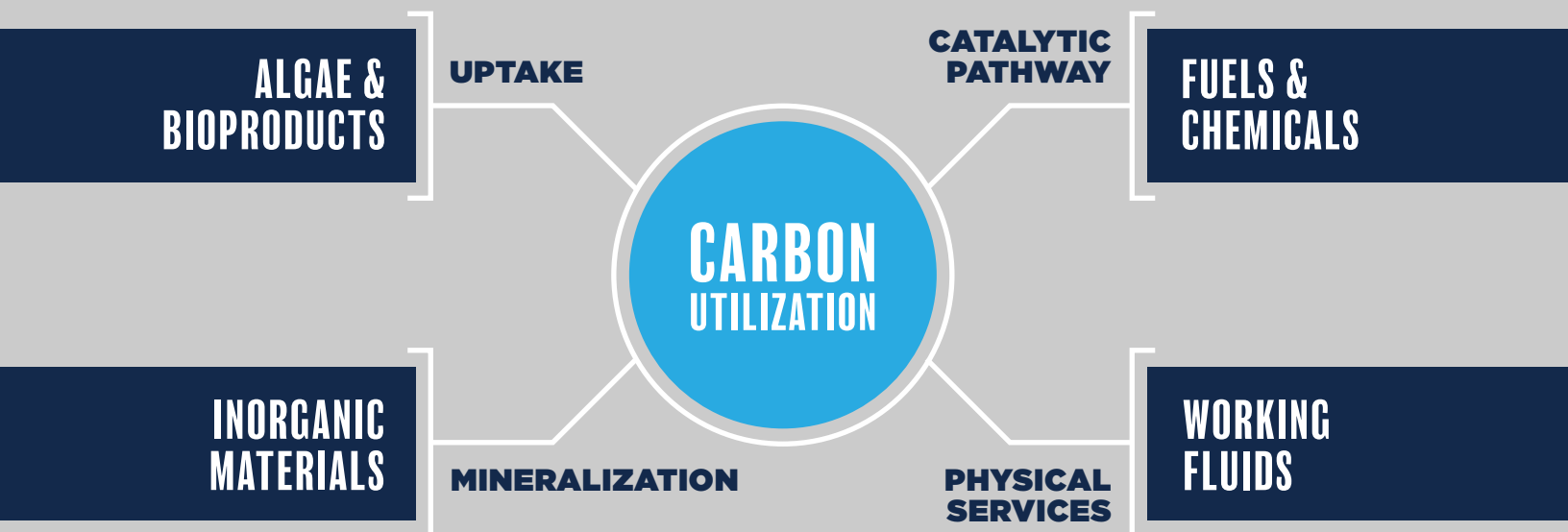


FIGURE 5. The efficient utilization of carbon dioxide (CO₂) is a long-term strategy to address carbon management across multiple sectors. The above carbon utilization options are happening across Illinois, but each has their own unique set of opportunities and research and development (R&D) challenges. For example, CO₂ can be utilized to “feed” algal systems, producing biomass that can be converted to biofuels, chemicals, animal food, and other products. To deploy CO₂ utilization technologies at an industrial scale, significantly more R&D is needed to reduce operating costs and improve the efficiency of these technologies.

ALGAE. Carbon dioxide can “feed” algal systems, producing biomass that can be converted to biofuels, chemicals, animal food, and other products. Global Algae Innovations has partnered with ISTC on a FEED study aimed at growing algae from flue gas generated by Dallman #4 at City Water, Light & Power (CWLP).

CONCRETE. CO₂ can be incorporated into the formulation of concrete. CarbonCure Technologies has commercialized the process of injecting CO₂ during the curing process, thereby strengthening the concrete.

CHEMICALS. ISTC is partnering with a small Chicagoland business to make Dimethyl Carbonate (DMC), a compound used in fabricating electric vehicle batteries, using captured CO₂.

CARBON FIBERS. Textile manufacturers have developed an emissions-to-textile process that uses methane and CO₂ emissions to produce fabric. Biotechnology company LanzaTech, based in Skokie, has partnered with Lululemon Athletica to create yarn and fabric using recycled carbon that would otherwise be emitted to the atmosphere as pollution.

POLYMERS. The carbon in CO₂ can be used in polymer production by replacing part of the fossil fuel-based raw material in the manufacturing process. Several companies are operating polymer plants using CO₂ as a raw material (Berghout & McCulloch, 2019).

STAKEHOLDERS ASKED

How much CO₂ will be beneficially reused?

Carbon utilization technologies hold promise for managing captured carbon. However, many CO₂ uses are still in the research and development stages and currently represent a relatively small amount of carbon utilization. No carbon utilization technologies can handle all captured carbon and completely replace the need for carbon storage, a technique that has the potential to remove vast quantities of CO₂ captured from a wide range of emission sources. Utilization offers research and economic opportunities and potential across Illinois.

At the time of the writing of this report, the U.S. DOE’s National Energy Technology Laboratory’s (NETL) Carbon Conversion Program offered funding opportunities with universities, national laboratories, industries, and regional partners to advance technologies for carbon utilization projects.

RECOMMENDATIONS

- Create incentives for use of products that utilize captured CO₂. Related examples of this include the low carbon fuel standards credit (Low Carbon Fuel Standard, California Air Resources Board) established in California.
- Consider incentives that encourage the development or use of products with the best CO₂ benefits.
- Consider enhancing support and consistent funding of CCUS research and development and large-scale demonstrations simultaneously.

CARBON STORAGE

This section details the process of carbon storage, explores Illinois' geology and carbon storage capacity, highlights the Illinois State Geological Survey's (ISGS) experience with carbon storage, addresses risks and permitting concerns, and concludes with a list of best practices for carbon storage in Illinois.

PUBLIC ACT 102-0341

Procedures, standards, and safeguards for the storage of CO₂

Liability for the storage and monitoring of CO₂ after the completion of a carbon capture, utilization, and storage project

Methodologies to establish any necessary fees, costs, or offsets

Any risks to health, safety, the environment, and property uses or values

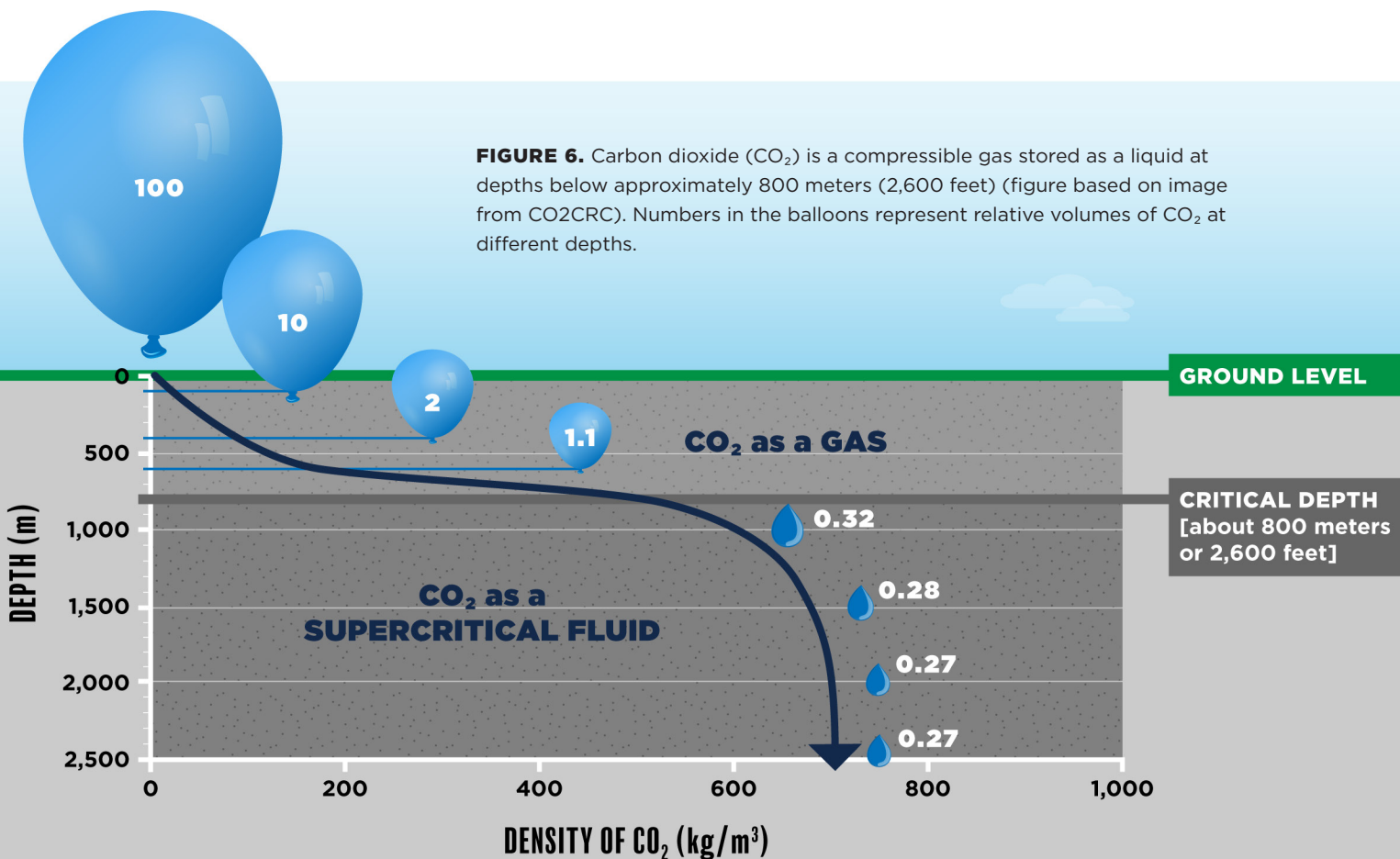
Permitting processes and the coordination with applicable federal law or regulatory commissions, the Class VI injection well permitting process

Geologic carbon storage or sequestration describes the process of injecting CO₂ into geologic strata for permanent storage to mitigate greenhouse gas emissions into the atmosphere. Carbon storage can use CO₂ from any source, whether it is a byproduct of ethanol production, separated from other emissions at a power plant, taken from cement plants, or removed from ambient air. Regardless of source, captured CO₂ is compressed, transported, and injected thousands of feet underground, permanently stored inside a suitable geologic formation. During the compression phase, the CO₂ is converted from a gas into a denser fluid defined chemically as a supercritical fluid, meaning that the CO₂ is liquid-like in that it has the density of liquid along with the mobility of gas. CO₂ is contained within the storage formation mainly by the presence of overlying strata (caprock) such as shales that are impermeable and act as barriers to fluid flow. Together, the storage formation and the caprock are referred to as a storage complex.

Characteristics of Suitable Geologic Storage Complexes

A common question about geologic storage is how appropriate geologic storage complexes are identified. The components required to make up an effective geologic storage complex are well understood. Three main factors determine if a geologic complex is appropriate for CO₂ storage:

- **Injectivity:** Can you put CO₂ in the rock?
- **Capacity:** How much CO₂ can you put in the rock?
- **Containment:** Can you keep the CO₂ in the rock?



Injectivity and Storage Capacity

For the requirements of injectivity and storage capacity, a geologic formation must be:

POROUS — The ideal reservoir for geological storage of CO₂ is sedimentary rock such as a sandstone having porosity (typically 10 to 25 percent pore space) and permeability (connectivity of the pores). Imagine a crate of oranges: the spheres touch in many places, but there are also gaps between the spheres. These gaps are similar to the pore space found between grains of rock deep underground. Rocks having suitable porosity and permeability allow CO₂ to be injected.

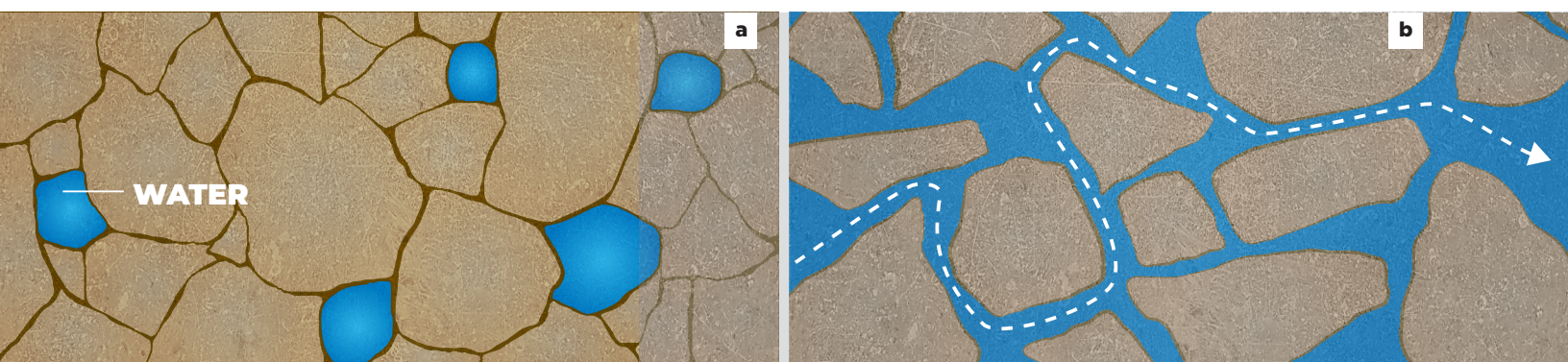


FIGURE 7. (a) Porosity is a measure of the amount of space available for storage in a rock. (b) Permeability is a measure of the ability of fluid to move as a result of the connectedness of those spaces. When supercritical carbon dioxide (CO₂) is injected into the formation, it displaces the existing fluid as it moves through the porous rock. As the CO₂ continues to move, small portions of the CO₂ can be left behind as disconnected, or residual, droplets in the pore spaces that are essentially immobile, just like water in a sponge.



FIGURE 8. Illinois Basin storage complex. (a) Mt. Simon Sandstone is the storage unit and the (b) Eau Claire Shale is the containment unit at the top that prevents carbon dioxide (CO₂) from escaping due to very low permeability.

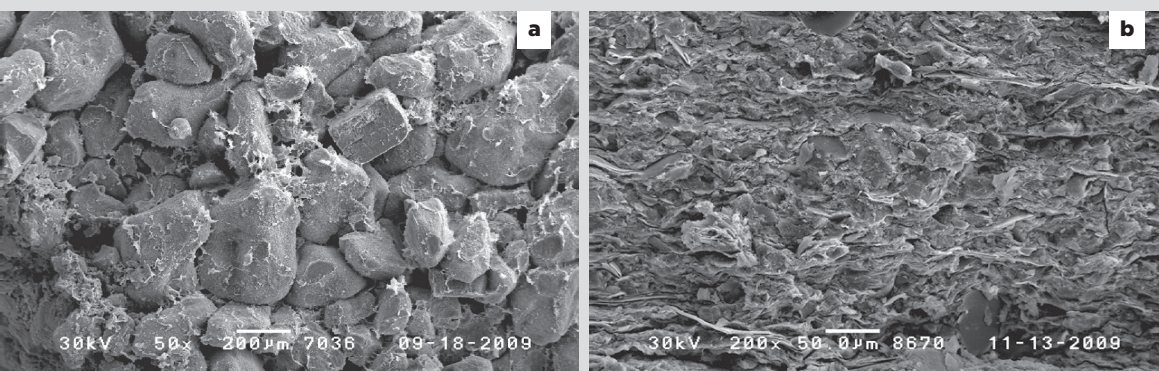


FIGURE 9. Micrographs depicting (a) Mt. Simon Sandstone available pore space for storage and (b) Eau Claire Shale sealing potential due to the very small and disconnected pore space.

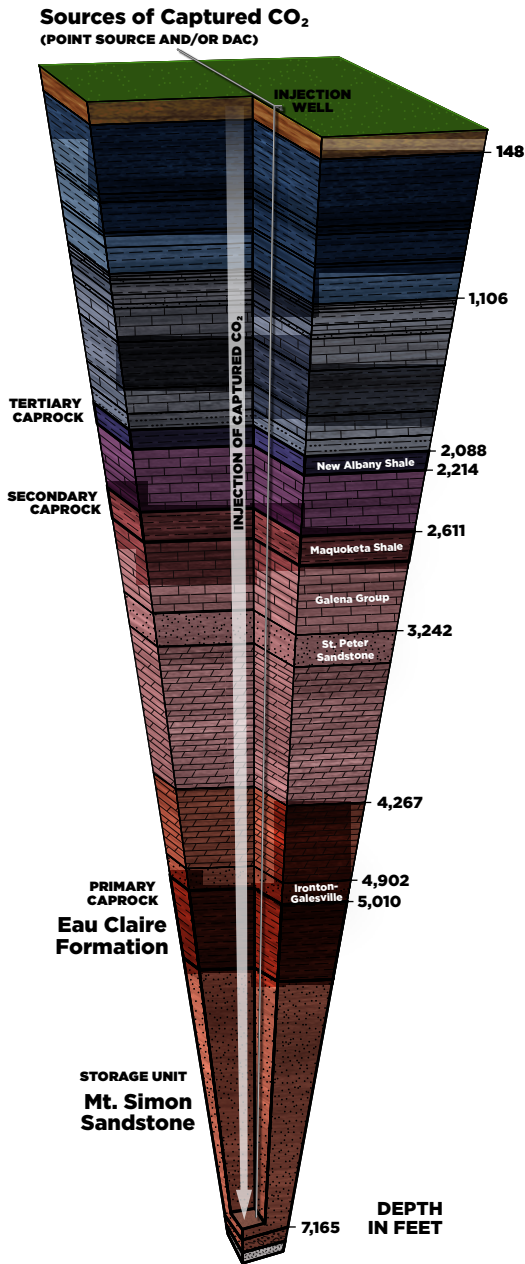


FIGURE 10. Carbon storage occurs at significant depths, often more than a mile beneath the surface, where it is isolated from shallow groundwater sources. For example, the CO₂ captured in the Illinois Basin — Decatur Project (IBDP) was injected through a well drilled into the Mt. Simon Sandstone at a depth of 6,800 feet, or more than a mile. Water wells in the region are generally less than 140 feet deep.

VERY DEEP — Deeper than about 3,000 feet is preferred because at these depths the Earth’s temperatures and pressures keep the CO₂ in a liquid-like state. As a result, the CO₂ is denser and less buoyant than in a gaseous state, which requires significantly less pore space and improves the efficiency of storage.

PROJECTS IN ILLINOIS TO DATE HAVE STORED CO₂ AT VERY DEEP DEPTHS, BETWEEN APPROXIMATELY 6,600 AND 6,800 FEET BENEATH THE SURFACE.

EXPANSIVE enough to provide significant volumes of pore space for storage.

OPTIMAL WATER SALINITY — Ideally this geologic formation would have water with a salinity greater than 10,000 milligrams per liter of total dissolved solids, not potable water based on the U.S. Environmental Protection Agency (EPA) regulatory framework under the Safe Drinking Water Act.

Containment

To keep CO₂ in the rock, a geological formation must be topped by layers of impermeable rock, such as shale, that restrict the vertical movement of fluids. These impermeable strata act as seals to retain CO₂ in the storage formation and are the same types of rocks that have held and continue to hold oil and gas in reservoirs for millions of years.

Characterization Methods

The methods used to identify and measure the characteristics of storage complexes are based on techniques used for oil and gas exploration and other geological investigations. In Illinois, for example, the ISGS has collected information on the subsurface geology of Illinois for more than 100 years.

The primary characterization methods include the following:

DRILLING STRATIGRAPHIC TEST WELLS. Stratigraphic or structural test wells are wells drilled to obtain geologic and engineering data at a specific location. In Illinois these wells are permitted by the Illinois Department of Natural Resources (IDNR). Data acquired from such wells include rock samples as cylindrical cores or rock cuttings and fluid samples from formations of interest. Geophysical measurements taken continuously along the wellbore or “logs” can provide additional information such as electrical, acoustic, temperature, and mechanical properties, all of which are used to evaluate the suitability of a given site. Well tests can be performed to study injection and pressure behavior. These data are used to identify the various rock layers and measure porosity, permeability, thickness, depths, and other data used for site evaluation.



FIGURE 11. Drilling rigs like the one shown above are used across various phases of the carbon storage process. During the exploration phase, they dig exploration wells to determine storage site suitability. In the development phase, they drill the injection wells for carbon dioxide (CO₂) and to perform maintenance during periods of active CO₂ injection. Lastly, they are used in the decommissioning phase for operations such as well plugging and abatement procedures.



FIGURE 12. Seismic imaging is used to provide a picture of what is happening underground. By using specially equipped trucks like the one shown above to send sound waves from the surface to bounce off the underlying rocks, scientists develop a seismic map of the subsurface.

CONDUCTING SEISMIC SURVEYS. Specially equipped trucks shake the earth to bounce sound waves off the underlying rocks, enabling scientists to develop a seismic map of the subsurface. These surveys are used to determine the lateral extent and continuity of the potential storage formation and seals and identify whether faults or fractures may be present.

PERFORMING GEOLOGIC AND ENGINEERING STUDIES based on well and seismic data and laboratory measurements. These studies collect information that is used to better understand the carbon storage complex, reduce impacts, and create monitoring systems. Further, information gathered is used in planning and risk assessments that provide essential pathways to protect human health and environmental safety.

DEVELOPING DETAILED GEOLOGICAL MODELS, such as 3D geocellular models that contain all the geological information for the site of interest and surrounding area, and performing computational simulations of the injection of CO₂ to determine where it will move during injection.

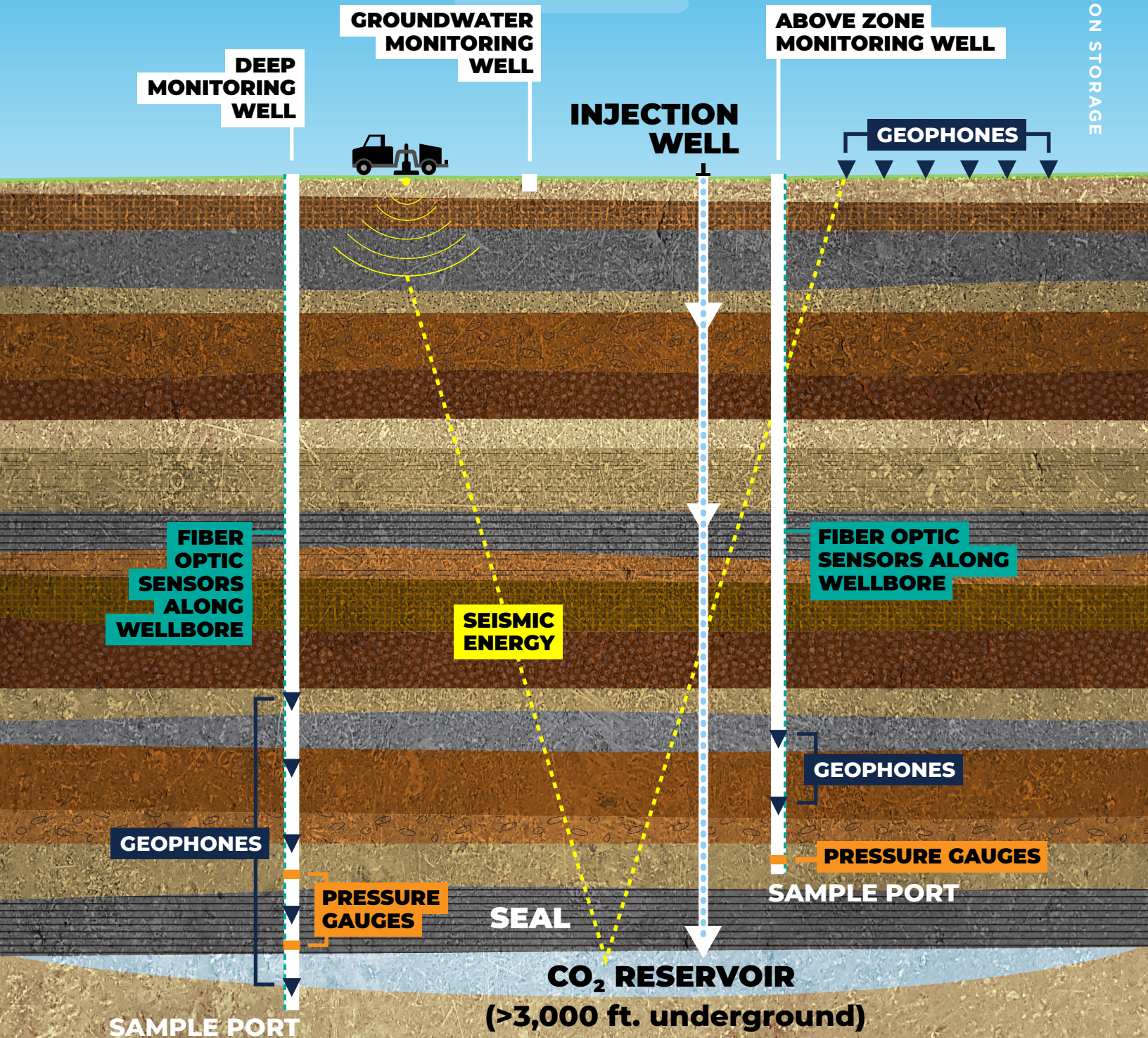


FIGURE 13. Many technologies are used to characterize carbon storage locations and monitor stored CO₂. Stratigraphic or structural test wells are wells drilled to obtain geologic and engineering data at a specific location and are used to study injection and pressure behavior. Seismic surveys are used to examine storage formation and seals, and to identify whether faults or fractures may be present. 3D geocellular models are used to perform computational simulations of the injection of CO₂ to determine where it will move during injection. Other geologic and engineering studies collect information to better understand the carbon storage complex, reduce impacts, and create monitoring systems.

STAKEHOLDERS ASKED

What's the history of
CCUS in Illinois?

STAKEHOLDERS ASKED

Is all of Illinois' geology
alike?

Illinois' Experience with Carbon Capture and Storage

ISGS has been conducting research on the characterization of geological carbon storage sites in Illinois for more than 20 years and the geology of Illinois since 1905. This activity has resulted in scientists and engineers in Illinois developing extensive knowledge and expertise in carbon capture and storage and in Illinois having some of the most detailed data for site characterization available.

The carbon storage experience in Illinois includes site screening studies, demonstration of CO₂ injection, and commercial-scale operations. Much of this work has been supported through U.S. DOE-sponsored projects led by, or involving, the Prairie Research Institute (PRI). Several of the carbon storage projects are summarized below.



FIGURE 14. Outline of the Illinois Basin, a geologic subsurface feature. The Illinois Basin is a massive oval depression that underlies roughly 70 percent of Illinois, extending about 60,000 square miles. Since the early 2000s, there has been strong interest in using the unique geology of the Illinois Basin to permanently store, or sequester, carbon dioxide (CO₂). The Mt. Simon Sandstone was among the first strata used to store CO₂, and the focus of the United States' first commercial-scale carbon sequestration project, the Illinois Basin — Decatur Project (IBDP).

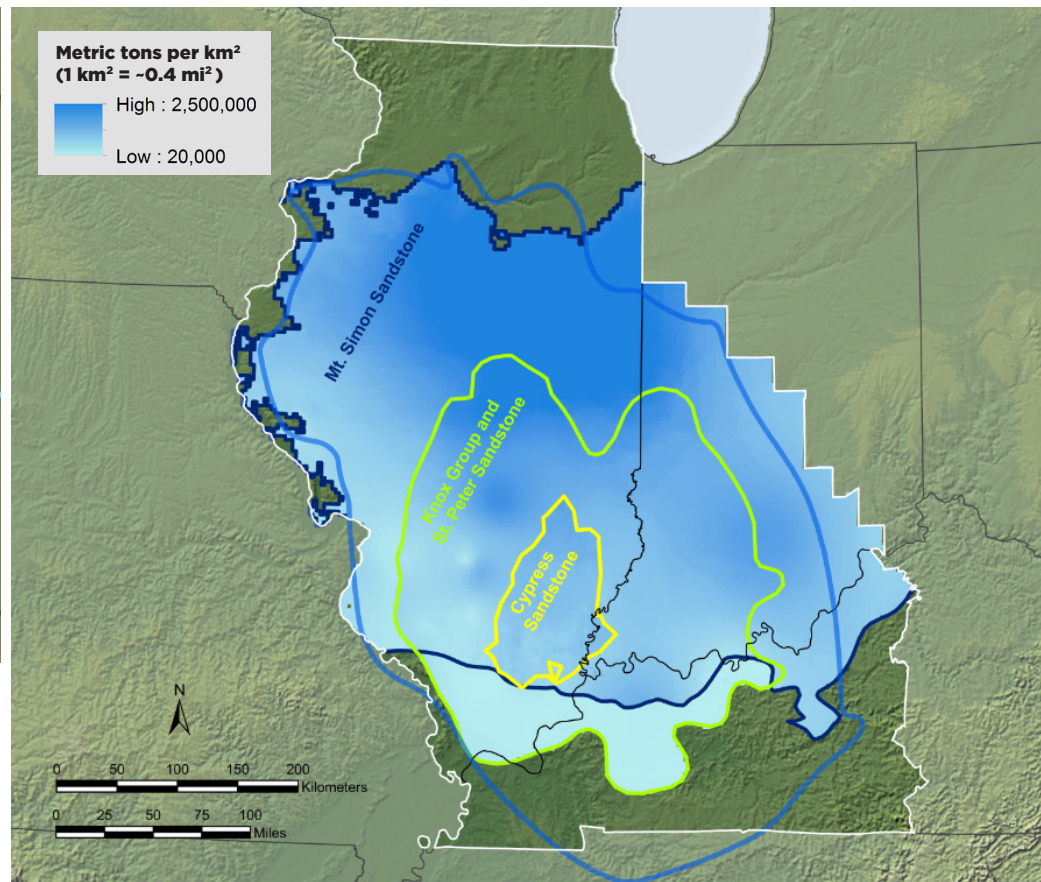


FIGURE 15. CO₂ storage resource for deep saline formations in the Illinois Basin region (modified from U.S. DOE, 2012). Map shows the regional storage resource within the project area (white outline) for the Mt. Simon, St. Peter, and Cypress Sandstones, and is largely a function of formation thickness and average porosity over areas where the formations are individually deeper than 2,500 feet (a general depth which represents minimum pressure and temperature conditions adequate to maintain CO₂ in the supercritical state). Note the Knox Group carbonates are not included in this resource tabulation, but their availability for storage generally follows the depth trend of the overlying St. Peter Sandstone. The regional map will be updated based on new data available after the time of its publication.

FutureGen and FutureGen 2.0

From 2006 to 2015, the U.S. DOE-funded FutureGen Projects were intended to design and characterize a geologic storage site with carbon capture on location ([FutureGen](#)) and carbon capture from a retrofitted plant in Meredosia (FutureGen 2.0). Although these projects did not reach an operations phase, significant site characterization measures from these projects have vastly contributed to understanding of the Illinois Basin geologic storage potential.

Illinois Basin — Decatur Project: 2007–2021

The [Illinois Basin — Decatur Project](#) (IBDP) captured and injected 1 million metric tons of CO₂ at the Archer Daniels Midland (ADM) facility in Decatur, Illinois. The project began with four years of pre-injection monitoring (2007–2011), injection monitoring (2011–2014), and post-injection monitoring (2014–2021). During the full project operation (2007–2021) the site in Decatur was continually monitored at the surface and in the subsurface, with monitoring continuing throughout the post-injection period. This effort demonstrated that the CO₂ has been geologically stored effectively and safely.

The IBDP was led by ISGS and carried out by the Midwest Geological Sequestration Consortium, one of seven [Regional Carbon Sequestration Partnerships](#) funded by the U.S. Department of Energy National Energy Technology Laboratory (U.S. DOE NETL). ISGS also worked with the Indiana Geological Survey (now the Indiana Geological and Water Survey) and the Kentucky Geological Survey as key partners. Other partners included ADM, Trimeric Corporation, Schlumberger, Brigham Young University, and Southern Illinois University.

THE CO₂ WAS CAPTURED FROM THE FERMENTATION OF CORN TO PRODUCE ETHANOL, THEN WAS COMPRESSED, DEHYDRATED, AND INJECTED THROUGH A WELL DRILLED INTO THE MT. SIMON SANDSTONE AT A DEPTH OF 6,800 FEET, MORE THAN A MILE DEEP. FOR REFERENCE, WATER WELLS IN THE REGION ARE GENERALLY LESS THAN 140 FEET DEEP.

STAKEHOLDERS ASKED

Are there specific areas in Illinois that are better suited than others for CO₂ storage?


Prior to the injection operations, the site underwent years of extensive geologic investigation, including drilling of wells, analyzing rocks, and collecting seismic information. This work mapped and described the characteristics for the storage complex and caprock. The Mt. Simon Sandstone was identified as an optimal storage formation because of its depth, expanse, and excellent porosity and permeability characteristics. The Eau Claire Formation overlies the Mt. Simon Sandstone and contains a thick package of impermeable shale that forms an excellent

caprock. These shales prevent any upward migration of CO₂, helping to ensure that it is all retained within the pore space of the Mt. Simon Sandstone. In addition to the caprock, there are multiple geologic barriers, including thick and widespread formations of impermeable shale within the thousands of feet of strata between the Eau Claire Formation and the surface.

The IBDP garnered international interest, welcoming more than 700 visitors from at least 29 countries, because of several key accomplishments:

- Demonstrated carbon capture and storage at a significant near-commercial scale. The objective of 1 million tons of CO₂ stored was reached effectively and safely, showing that capture and storage could be scaled up to manage typical annual emissions of industrial operations.
- Acquired one of the first U.S. EPA Underground Injection Control (UIC) Class VI permits (the class of permit specifically for wells used for geologic sequestration of CO₂).
- Developed a first-of-its-kind monitoring, verification, and accounting (MVA) program that requires monitoring during and after injection to verify that the stored CO₂ stays in place and does not cause environmental damage. Monitoring techniques include using geophysical technology to confirm the position of the CO₂ underground and wells to monitor shallow groundwater and soils.
- Demonstrated that Illinois has optimal geological conditions for permanent sequestration of greenhouse gases.

Industrial Carbon Capture Storage Project

The Illinois Industrial Carbon Capture and Storage Project (ICCS), also backed in part by funding from the U.S. DOE, is conducted at the ADM facility in Decatur, IL and builds on the success and findings of the IBDP. The purpose of the ICCS is to reach commercial-scale capture and storage operations. Although the IBDP was designed to dehydrate and compress up to 1,000 metric tons of CO₂ per day, the ICCS dehydrates and compresses three times that amount of CO₂ per day and can store up to 3,000 tons of CO₂ per day in the Mt. Simon Sandstone for permanent sequestration. The ICCS injection and monitoring wells are about 1 mile north of the IBDP site, and injection operations at ICCS have been active since 2017. According to the [U.S. EPA's Greenhouse Gas Equivalencies Calculator](#) :

OVER 4 MILLION METRIC TONS OF CO₂ HAVE BEEN INJECTED AT ICCS AS OF LATE 2022, WHICH IS THE EQUIVALENT OF 861,877 GASOLINE-POWERED PASSENGER CARS DRIVEN FOR ONE YEAR.

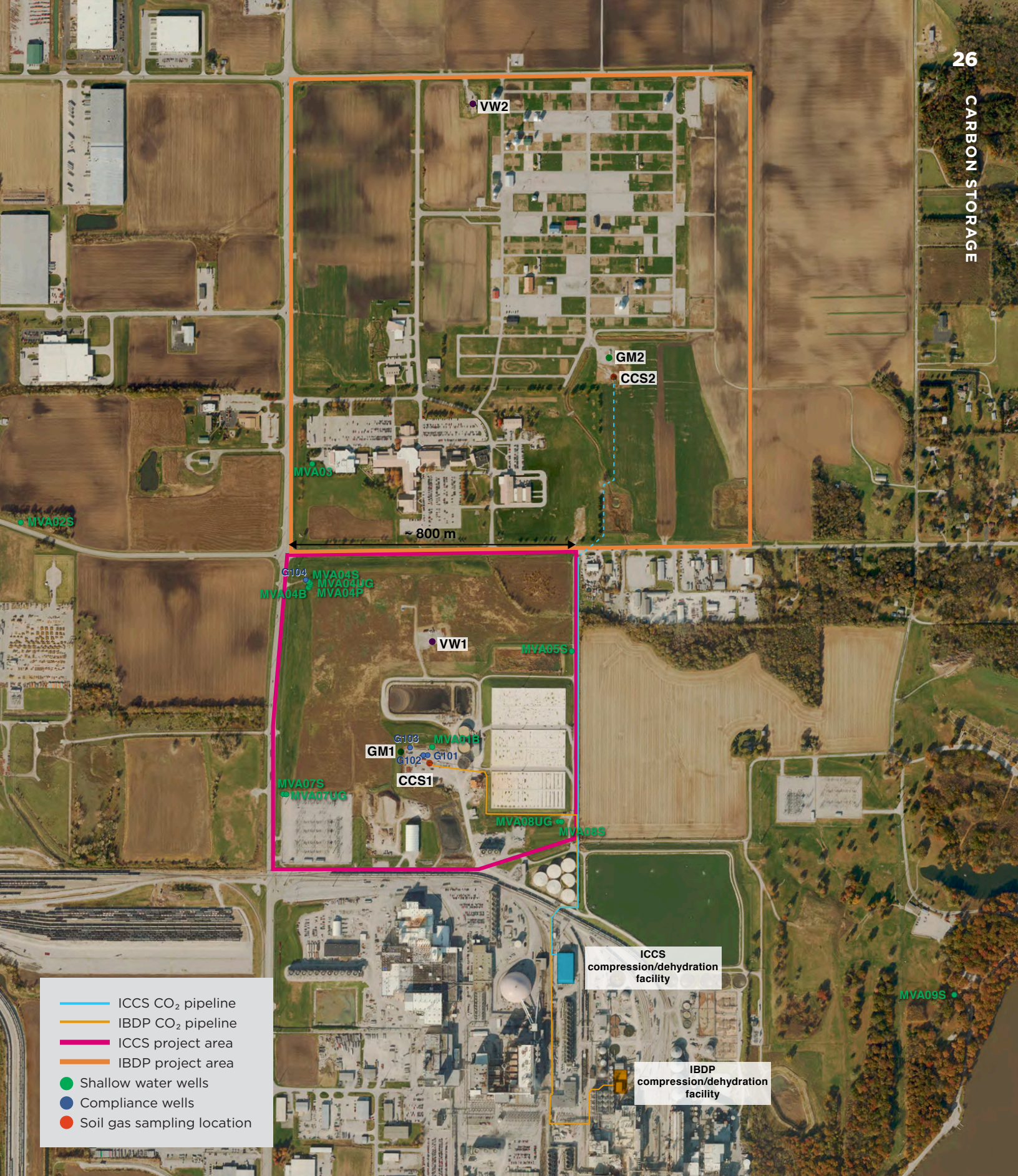


FIGURE 16. Aerial photograph showing the Illinois Basin — Decatur Project (IBDP) and Illinois Industrial Capture and Storage Project (ICCS) at Decatur. Image courtesy of Midwest Geological Sequestration Consortium (MGSC).

CarbonSAFE

The [Carbon Storage Assurance Facility Enterprise](#) (CarbonSAFE) is a current U.S. DOE initiative that began in 2016 with the goals of understanding and further reducing technical risks and bringing down costs of commercial-scale (>1 million metric tons per year injection) carbon storage. ISGS has led four CarbonSAFE projects to evaluate the feasibility of storing CO₂ in strata of the Illinois Basin by drilling test wells and conducting extensive seismic surveys. In addition to the Mt. Simon Sandstone, the CarbonSAFE program has identified several other formations that are highly suitable for carbon storage in the Illinois Basin.

CARBONSAFE ILLINOIS STORAGE CORRIDOR

(10/01/2020 -09/30/2023)

This Phase 3 CarbonSAFE project aims to accelerate commercial deployment of carbon capture, utilization, and storage within the Illinois Storage Corridor, a region with proven geologic storage performance and numerous industrial carbon sources. The Illinois Storage Corridor project will involve characterizing and constructing two carbon storage sites: one near the [One Earth Energy ethanol facility](#) in Gibson City, Illinois, and a second at the Prairie State Generating Company in Marissa, Illinois. Combined, the sites will have the capacity to store 6.5 million metric tons of CO₂ annually.

CARBONSAFE ILLINOIS MACON COUNTY

(04/01/2017-03/31/2021)

ISGS and partners Schlumberger Carbon Services, Indiana Geological Survey, Brigham Young University, and Richland Community College are working to conduct a Phase 2 commercial-scale initial characterization of a site within the Mt. Simon storage complex and develop datasets of formation parameters to evaluate the suitability of the site located in Macon County, Illinois. The models will be used to identify improvements in storage capacity estimations.

CARBONSAFE WABASH

(02/01/2019-05/31-2021)

This project is designed to establish the Phase 2 feasibility of developing a commercial-scale CO₂ storage complex near Terre Haute, Indiana, in the Mt. Simon Sandstone, which is expected to be the primary storage reservoir. Other potential storage reservoirs will be characterized by a two-year data acquisition program that includes drilling and testing alongside core and fluid sample collection and analysis, and a two-dimensional seismic survey over the area.

CARBONSAFE ILLINOIS EAST-SUB BASIN

(03/01/2017-10/31/2019)

Completed in 2019 as part of the Integrated Carbon Capture and Storage Pre-Feasibility (Phase 1) of the CarbonSAFE Initiative, the University of Illinois and ISGS conducted a pre-feasibility assessment for commercial-scale CO₂ geological storage complexes in the East Sub-Basin of the Illinois Basin. A significant high-level technical evaluation of the East Sub-Basin includes detailed subsurface characterization and risk identification, along with the evaluation of potential industrial CO₂ sources for sequestration, to identify suitable storage sites within the complexes. Storage resource estimates in the CarbonSAFE pre-feasibility region suggest that there is sufficient storage capacity in the reservoirs of the Cambrian-Ordovician units in the Midwestern region.

Future Storage Projects in Illinois

At the time of this report, three permits have been submitted to the U.S. Environmental Protection Agency (U.S. EPA) Region V in Chicago for consideration (two in Illinois and one in Indiana). Given the suitability of the Mt. Simon Sandstone for geologic storage of CO₂, it is likely that the Illinois Basin will continue to be a desirable location for these activities and that multiple projects will be proposed. However, due to variations in the geology of the Illinois Basin, detailed geological characterizations will be needed via detailed subsurface characterization, modeling, and monitoring at all proposed storage sites.

Federal Permitting of Carbon Injection and Storage

STAKEHOLDERS ASKED

If the plan is for Illinois to go carbon free in 2050ish, are we going to be taking in carbon from other states that don't go carbon free?

All carbon storage projects in Illinois are currently regulated by the U.S. EPA under the authority of the Safe Drinking Water Act as part of the Underground Injection Control (UIC) program. The U.S. EPA regulates the construction, operation, permitting, and closure of all injection wells (wells that place fluids underground for storage or disposal) to protect underground sources of drinking water (USDWs). A USDW is defined in Title 40, Code of Federal Regulations (40 CFR), Section 144.3 as having fewer than 10,000 milligrams per liter of total dissolved solids. There are six categories, or classes, of underground injection wells (see Table 1). [UIC Class VI](#) regulates the siting, construction, operation, testing, monitoring, and post-injection site care (PISC) of wells for the injection and storage of CO₂. The U.S. EPA's UIC Class VI Wells program offers recommendations for incorporating [public participation measures](#) into state CCUS projects. Class VI regulations are outlined in the Code of Federal Regulations parts [40 CFR 144 Subparts A through E](#) as well as [40 CFR 146 Subpart H](#).

TABLE 1. Underground Injection Control categories.

Underground Injection Control Class	Description
Class I	Inject hazardous and non-hazardous wastes
Class II	Inject fluids associated with oil and natural gas production, primarily brines
Class III	Inject fluids to dissolve and extract minerals
Class IV	Banned since 1984, these shallow wells were used to deposit hazardous or radioactive waste into or above a geologic formation containing a USDW.
Class V	Inject non-hazardous fluids underground into or above the lowermost USDW. This class includes stormwater drainage wells, septic system leach fields, and agricultural drainage wells
Class VI	Inject carbon dioxide deep underground into geologic storage complexes for permanent sequestration or storage

CLASS VI PERMITTING REQUIREMENTS FROM THE U.S. EPA UNDERGROUND INJECTION CONTROL (UIC) PROGRAM CLASS VI IMPLEMENTATION MANUAL FOR UIC PROGRAM DIRECTORS

Characterize the site by assessing the local and regional geology and hydrogeology to ensure the storage complex has sufficient capacity and confining rock layers that are free of transmissive faults or fractures.

Construct wells of materials that are compatible with and can withstand contact with CO₂ over the life of a project and that will prevent endangerment to USDWs.

Review planned operations to ensure that well injection rates and volumes are suitable to site-specific geology and ensure that injection operations do not endanger USDWs.

Monitor storage well integrity, CO₂ injection and storage, and groundwater quality during the injection operation and the post-injection site care (PISC) period.

Provide financial assurance and ensure adequate funds are available for the storage project's life and PISC period.

Report and keep records that show continual evaluation of Class VI operations and that verify protection of USDWs.

As of September 30, 2022, U.S. EPA Region V (consisting of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin) has permitted six Class VI wells, two of which are active and at the ADM sites in Decatur, Illinois, and four of which were issued for the FutureGen 2.0 project but never used. Two additional permit applications for Illinois (Macon and Putnam counties) are pending.

THE CLASS VI PERMITTING PROCESS REQUIRES EXTENSIVE DOCUMENTATION AND DATA TO SUPPORT AN APPLICATION.

The work required to prepare the federal permit documentation and plans is comparable to the requirements for characterizing a storage complex and may include drilling a test well, conducting seismic surveys, and preparing detailed geological models and computational simulations of the injection process throughout the project's lifespan including up to 50 years post-injection.

THE U.S. EPA HAS PUBLISHED A SERIES OF GUIDANCE DOCUMENTS TO HELP REGULATORS AND PROJECT DEVELOPERS TO COMPLY WITH THE UIC PROGRAM CLASS VI GEOLOGIC SEQUESTRATION REQUIREMENTS.

In addition to site characterization data, tables, maps, well design specifications, and demonstrations of financial responsibility by site operators, each permit application must also include five project plans:

1. **Area of Review (AoR) and Corrective Action Plan** (40 CFR 146.84(b))—describing how the operator determines the AoR for the project and ensuring that other wells in the area, if present, will be addressed by corrective action techniques so that they will not become conduits for fluid movement into USDWs.
2. **Testing and Monitoring Plan** (40 CFR 146.90)—describing how the owner or operator intends to perform all necessary testing and monitoring associated with the storage project.
3. **Injection Well Plugging Plan** (40 CFR 146.92(b))—describing how, following cessation of injection, the owner or operator intends to plug the Class VI injection well using the appropriate materials and methods.
4. **Post-Injection Site Care (PISC) and Site Closure Plan** (40 CFR 146.91(c))—describing how the owner or operator intends to monitor the site after injection has ceased (the default duration for the PISC period is 50 years).
5. **Emergency and Remedial Response Plan** (40 CFR 146.94(a))—describing the actions that the owner or operator intends to take in the event of movement of the injected CO₂ or formation fluids in a manner that may cause danger to a USDW, including the appropriate people to contact.

Identifying and Managing Risk Associated with Carbon Storage

The process of identifying and defining methods and procedures to manage and mitigate risk are critical in site selection, characterization, and design processes. Site selection is the foremost function of this preliminary work and is informed through risk assessments and the Class VI permit application and compliance process.

DETAILED AND SPECIFIC PLANS FOR SITE MONITORING, MITIGATING RISK, AND ANY REMEDIAL RESPONSES ARE PRIMARY COMPONENTS OF CLASS VI PERMITS FOR ALL CARBON STORAGE PROJECTS.

Carbon capture and storage project developers conduct systematic risk assessments throughout their development and operational phases that include a registry of site-specific risks and processes to mitigate and manage throughout the life of a project. Risk assessments include evaluating a site's geology to assess its suitability for storage, operation while CO₂ is being injected deep underground, and post-operation throughout the federally mandated PISC period (typically 50 years after injection has ended), during which the operator is required to continue to monitor the site.

The risks or uncertainties associated with a specific project and contained in that project's risk registry are commonly categorized using a matrix that compares the likelihood of occurrence versus the potential impact or consequence. Consequences can be measured in terms of financial cost, time delays, system performance, health and safety, and environmental protection. Those risks that are determined to have a high likelihood and high impact must be addressed and reduced or eliminated through the choice of alternative processes, materials, engineering designs, or monitoring methods. The risk analysis in a project is an iterative process, in which each risk is managed and new risks are assessed until plans are designed to continue to reduce uncertainty and improve system performance. Risks that have a low likelihood or low consequences are continually managed through the project by ongoing measurement and monitoring.

An integrated CCUS project for CO₂ capture, transport, and storage involves a wide range of technologies, most of which have been in standard industrial use for decades and for which risk profiles are well understood. Geologic storage is an area less familiar to many, but many of the measurement and monitoring techniques and operational parameters have been in use by industry in oil and gas or disposal operations for many years. A feature unique to geologic storage of CO₂ is the requirement for a robust monitoring program for projects to gain approval to inject under the U.S. EPA Class VI regulations. Projects are required to have dedicated monitoring wells in the zone of

injection to allow for periodic sampling and other measurements and monitoring wells above the injection zone at various depths depending on the geology of the site. These wells are typically instrumented with a range of sensors that might include fiber optic lines along the length of the well along with pressure and acoustic gauges. There is a wide range of monitoring methods, which includes subsurface and surface geophysical measurements such as repeat seismic surveys ([Figure 13](#)). Shallow wells are also used to monitor near-surface groundwater, and baseline surveys are conducted to determine naturally occurring environmental parameters prior to injection. Monitoring and remedial action plans are required documents for all projects and are subject to revision and updating throughout the project's life.

Stakeholders often express concern about whether geologic storage sites will leak, what happens if a site does leak, and whether geologically storing CO₂ will cause earthquakes. Each of these issues is addressed below.

STAKEHOLDERS ASKED

Will the injection pressure return to the pre-injection level once the injection stops? How long does that take?

CO₂ Leakage

The injection of CO₂ into a storage reservoir involves displacing the existing formation brine contained in the pores of the rock. Although some CO₂ dissolves into the brine, most remains as a discrete fluid that may cause a pressure increase within the injection zone. This pressure change is continuously monitored during operations and, by regulation, each injection project has a maximum pressure threshold based on the specific geophysical or mechanical characteristics of the site's reservoir. As regulated by the UIC program, the pressure differential, that is, the change from the original pressure to the higher pressure during the injection of CO₂, is used to define the area that will be monitored. The area of review (AoR) is typically larger than the area occupied by the injected CO₂.

STAKEHOLDERS ASKED

What are the environmental issues and potential local hazards if the CO₂ leaks?

Carbon dioxide could potentially leak out of the confining caprock if there is a thinning or change of caprock type, or if faults or fractures are present through the caprock. However, these potential risks can be addressed with a relatively high degree of confidence using seismic surveys, geophysical well logs, rock analyses, well tests, and regional mapping. It is important to note that only sites with a demonstrated high degree of storage integrity receive federal permits. Another type of leakage risk occurs when there are pre-existing, or legacy, well bores. This can be addressed by identifying all wells in the AoR and conducting a thorough evaluation of those that are deep enough to reach through the caprock to determine their integrity. In some cases, remediation of these deep wells can be achieved by plugging with cement as a requirement before an injection permit is authorized. All wells drilled as part of the injection project are also required to be fitted with instruments to allow for monitoring and are subjected to annual mechanical integrity testing. The probability of leakage risk associated with possible CO₂ leakage pathways is presented in the [Final Risk Assessment Report for the FutureGen Project Environmental Impact Statement, revised April 2007](#). A modified version of the table is presented below.

STAKEHOLDERS ASKED

Can you monitor to know that CO₂ is not leeching into a property that doesn't have rights?

THE PRIMARY GOAL OF THE FEDERAL UIC CLASS VI REGULATIONS IS TO ENSURE THAT UNDERGROUND SOURCES OF DRINKING WATER ARE NOT CONTAMINATED BY INJECTED CO₂.

Federal regulations require monitoring plans be put in place to mitigate this risk and detect any potential leakage in the subsurface. Routine groundwater sampling from shallow wells should be performed and compared to pre-injection baseline values. When combined with fresh water, CO₂ can form a mild or weak acid called carbonic acid, similar to the acidity found in rainwater or carbonated beverages.

TABLE 2. Risk event probability.

Risk Event Type	Annual Probability	Number of Wells
Undocumented Deep Well Leak	0.1% per well ^a	2
CO ₂ Injection Well Leak	0.001% per well ^b	3
Deep CO ₂ Monitoring Well Leak	0.001% per well ^c	2
Rapid Leakage Through Caprock	0.00000002% ^d	n/a
Slow Leakage Through Caprock	0.004% ^e	n/a
Release Through Existing Faults	0.000002% ^f	n/a
Release Through Induced Faults	0.000002% ^g	n/a
Leakage Through Caprock/ Faults then Shallow Well	0.008% ^h	34

Source for risk events and annual probabilities: [Final Risk Assessment Report for the FutureGen Project Environmental Impact Statement, revised April 2007](#), at p. 6-15, Table 6-11. Additional Notes:

- a) Highest probability within FutureGen range for undocumented deep wells developed from the FutureGen analog database.
- b) Highest probability within FutureGen range for CO₂ injection wells developed from the FutureGen analog database.
- c) Conservatively assumed to be equal to CO₂ injection well leak probability.
- d) Equal to FutureGen probability for rapid leakage through caprock developed from the FutureGen analog database.
- e) Equal to FutureGen probability for slow leakage through caprock developed from the FutureGen analog database.
- f) Equal to FutureGen probability for release through existing faults developed from the FutureGen analog database.
- g) Equal to FutureGen probability for release through induced faults developed from the FutureGen analog database.
- h) Conservatively assumed to be twice as likely as the highest caprock/fault probability.

There is also the possibility that the carbonic acid could react with other minerals in rock formations in the aquifer and release other elements into the water. These changes are monitored by frequent and repeated testing of groundwater near a storage location. Monitoring the changes in geology and chemistry at a carbon storage site is one of the main methods for addressing leakage. In the event of leakage, CO₂ injection would be terminated and the well remediated before resuming operations.

Induced seismicity

Stakeholders expressed concern that carbon storage could cause earthquakes, also known as induced seismicity, and is related to how pressure is distributed due to the injection of CO₂. Induced seismicity risks are managed by characterizing the storage strata and thoughtfully designing injection parameters, and through ongoing monitoring. Monitoring for induced seismicity is done through active and passive seismic monitoring and is accomplished by installing geophones that will continuously record any changes in frequency or magnitude of microseismic activity. Information from these geophones can be used to effectively adjust injection rates and related pressure constraints.

The potential for induced seismicity associated with CO₂ storage was evaluated in the previously described Illinois Basin — Decatur Project (IBDP). Geophones were placed in deep well bores at the IBDP research site to detect sound waves associated with CO₂ injection and remained active prior to, during, and after CO₂ injection. During a three-year injection operations period, a notable increase of approximately 5,000 microseismic events were detected.

THE MAGNITUDE OF THESE EVENTS RANGED FROM -2 TO 1, WHICH IS COMPARABLE TO THE AMOUNT OF ENERGY RELEASED FROM DROPPING A TEXTBOOK ONTO A TABLE.

The depths at which these microseismic events occurred are more than a mile beneath the surface and were detected using the deep sensors. Seismic events are felt at the surface only when they reach a magnitude 3 or larger. The *largest* seismicity observed at the IBDP reached a magnitude of 1, which released 1,000 times *less* energy than a magnitude 3 earthquake. The smallest seismicity observed had a magnitude of -2, which released 31.6 *million* times *less* energy than a magnitude 3 earthquake. Notably, most of the associated microseismic events at the IBDP happened below the CO₂ injection zone in the harder Precambrian rocks that form the “basement” of the Illinois Basin. Based on these observations and to mitigate the occurrences of microseismicity, an injection well drilled 1 mile north at the Illinois Industrial Carbon Capture and Storage Project (ICCS) was designed to inject into a zone about 150 feet higher than at IBDP. Even when injecting at a higher rate (more CO₂ per day), the microseismic activi-

ty at ICCS is significantly lower. This change in response is an example of how research provides important insights that inform commercial operations. Microseismic events in Decatur were avoided at the ICCS project by moving the injection slightly higher at ICCS and reducing the influence of CO₂ in deeper basement rock, which is where the microseismic energy release was taking place at IBDP.

**IT HAS BEEN DEMONSTRATED IN ILLINOIS THAT
MICROSEISMIC ACTIVITY CAN BE REDUCED BY
ADJUSTING INJECTION LOCATION AND RATE.**

Guidance and Best Practices for Carbon Storage

In addition to the series of guidance documents published by the U.S. EPA to support compliance with the UIC program Class VI geologic sequestration regulations, there are non-governmental and international standards regarding carbon storage. These voluntary standards instruct operators on how to design CO₂ capture, transportation, and storage systems. These standards can also be incorporated into laws and regulations (Penn Program on Regulation, 2022).

The American National Standards Institute (ANSI) published a **standard for geologic storage in 2012** that was reaffirmed in 2017. This standard, “Z749-12 Geological Storage of Carbon Dioxide,” was developed by a U.S.-Canada binational technical committee associated with the CSA Group (formerly the Canadian Standards Association). The ANSI standard establishes requirements and recommendations for the geological storage of CO₂ to promote environmentally safe and long-term containment of CO₂ to minimize risks to the environment and human health. It includes “the safe design, construction, operation, maintenance, and closure of storage sites” and “provides recommendations for the development of management documents, community engagement, risk assessment, and risk communication” (ANSI, 2017).

In 2017, the International Organization for Standardization (ISO), a non-governmental international organization with a membership of 167 national standards bodies, published standards for CO₂ capture, transportation, and storage (**ISO 27914-17**). The standards aim to “minimize risk to the environment, natural resources, and human health” and cover “activities associated with site screening and selection, characterization, design and development, operation of storage sites, and preparation for site closure” as well as “requirements and recommendations for the development of management systems, community and other stakeholder engagement, risk assessment, risk management and risk communication.” (ISO, 2017)

STAKEHOLDERS ASKED

It’s important to engage local officials — even if a single drilling rig is one county. Who is responsible to keep local governments informed?

ISO standards are created through international collaboration on best practices gathered from global projects and reviewed every five years, so technical revisions to ISO 27914 are underway and include a new

clause on quantification and verification of CO₂ in the subsurface. The ISO standard development process ensures that the most up-to-date practices are available for application with projects.

U.S. Department of Energy

The U.S. DOE has published a series of best practice manuals to share lessons learned through its sponsored research and development activities. The best practices were first published in 2011 and were updated in 2017 to incorporate lessons learned from the large-scale field projects conducted by the regional carbon sequestration partnerships including the Midwest Geological Sequestration Consortium (MGSC) led by ISGS.

The **U.S. DOE Best Practice Manuals** are:

- Monitoring, Verification, and Accounting (MVA) for Geologic Storage Projects
- Public Outreach and Education for Geologic Storage Projects
- Site Screening, Site Selection and Site Characterization for Geologic Storage Projects
- Risk Management and Simulation for Geologic Storage Projects
- Operations for Geologic Storage Projects
- Geologic Formation Storage Classification

U.S. DOE has also published **guidance, documentation templates, training resources, and a toolkit** for CO₂ utilization life cycle analysis (LCA).

RECOMMENDATIONS

- **Consider establishing a state-level oversight authority that appropriately addresses the concerns of local governmental bodies.**
- **Incorporate federal law and regulation for underground carbon storage into state law and empower the appropriate agency(ies) to coordinate carbon storage activities.**
- **Encourage direct coordination between federal, state, and local governments for permitting and regulating underground carbon storage locations and setting operational standards.**
- **Encourage the development of a clear process for state requirements and guidelines for siting, permitting, and oversight of carbon storage projects not already regulated by federal processes.**
- **Create legal and regulatory frameworks for the long-term (post-closure) stewardship and oversight of geologic storage sites.**

POLICY CONSIDERATIONS IN ILLINOIS

This section addresses additional policy and stakeholder issues that need clarity for the state. A separate law and policy supplement accompanies this report.


PUBLIC ACT 102-0341

The current status and future storage resource potential in the state

Acquisition, ownership, and amalgamation of pore space for carbon capture, utilization, and storage

Liability for the storage and monitoring of the CO₂ after the completion of a carbon capture, utilization, and storage project

Illinois has geological conditions favorable for the permanent storage of CO₂ as demonstrated by active CCUS projects and as evidenced by decades of research. Through the work of the Midwest Geological Sequestration Consortium, the viability of the Illinois Basin for carbon storage has been verified. The Illinois Basin, which underlies most of Illinois, southwestern Indiana, and western Kentucky, was among the areas that USGS identified as having significant CO₂ storage potential.

The Illinois Basin is a bowl-shaped geological feature that holds thousands of feet of rock, including layers of porous sandstones and impermeable shales. The Mt. Simon Storage Complex as described earlier and used by both the IBDP and ICCS projects at Decatur is widely distributed within portions of the Illinois Basin. Based on the thickness and extent of the Mt. Simon Sandstone, the ISGS has estimated that this storage complex alone has the capacity to store from 11 billion to 150 billion tons of CO₂. According to the [U.S. EPA Greenhouse Gas Equivalencies Calculator](#) 



11 BILLION METRIC TONS OF CO₂ IS THE EQUIVALENT OF GREENHOUSE GASES PRODUCED BY MORE THAN 2 BILLION GASOLINE-POWERED PASSENGER CARS DRIVEN FOR A YEAR, OR THE CO₂ EMISSIONS OF MORE THAN 27,000 NATURAL GAS-FIRED POWER PLANTS OPERATING FOR A YEAR.

The Mt. Simon Sandstone is just one of several potential storage complexes in the Illinois Basin that include combinations of porous stone capped by impermeable rock at different depths that can be used for carbon storage. The ISGS is exploring the storage potential of these complexes through ongoing research supported in part by the U.S. Department of Energy.

Ownership and Control of Pore Space in Illinois

STAKEHOLDERS SAID

We need clarification on pore space ownership and CCUS.

Illinois has *not* explicitly addressed ownership of pore space for carbon storage through legislation. Given Illinois' well-defined subsurface property law relating to the extraction of minerals, however, there is an assumption that Illinois courts would recognize property rights to the subsurface, including pore space. Under the Illinois Severed Mineral Interest Act, for example, an owner of land is entitled to the surface and all that is below it, unless it is a [mineral estate](#)  (Kusmierczak, 2020). Also, in Illinois, a mineral estate can be [legally severed](#)  from the surface estate, and either estate can be conveyed or leased to another party.

Additional legislative guidance relevant to ownership and integration of pore space in Illinois can be found in existing state laws, including

STAKEHOLDERS SAID

Illinois is clearly of interest to industrial stakeholders wishing to develop commercial-scale carbon storage projects; however, landowners and project developers have identified several legal and policy areas related to CCUS that, if left unaddressed, could impact stakeholder decisions to support or invest in CCUS projects in Illinois. These include the issues of ownership and integration of pore space, long-term liability, and carbon storage on state-owned land.

STAKEHOLDERS SAID

It's tough for landowners to swallow when companies just offer a deal and say take it or leave it. Carbon storage is so new and we don't know a lot about it.

STAKEHOLDERS ASKED

Who takes responsibility for a CO₂ storage site if the entity declares bankruptcy?

those of neighboring Indiana, which address pore space ownership, integration, and unitization within the context of CCUS (additional information can be found in the [CCUS Law and Policy Supplement](#)).

Integration and Unitization in Illinois

Carbon storage operators and landowners alike have sought clarification as to what laws or regulations exist in Illinois regarding the integration of pore space. In other words, when a carbon storage operator wants to obtain legal permission to use the pore space underlying land owned by multiple parties, do all landowners need to agree to use of the pore space, or is it sufficient to obtain permission of a certain percentage of the landowners?

Although Illinois has not explicitly addressed this question with respect to CCUS, the [Illinois Oil and Gas Act](#) (225 ILCS 725) and its implementation regulations address similar questions regarding oil and gas rights. When oil or gas rights within a drilling unit are separately owned, and the owners of those rights have not voluntarily agreed to integrate those rights to develop the oil or gas, an owner can petition the Illinois Department of Natural Resources (IDNR) for an order to integrate their property interests and develop their lands as a single drilling unit. If landowners do not agree to integration, but at least one landowner has already drilled or proposed to drill for oil or gas, IDNR can require all landowners to develop their lands as an integrated drilling unit to prevent waste and unnecessary drilling.

Where separately owned tracts of land share a common pool of oil or gas or both, the Illinois Oil and Gas Act allows any interested person to petition IDNR for an order that “unitizes” those tracts, treating them as a single unit for the purpose of recovering oil and gas. The petition must include the proposed unitization plan signed by the owners of at least 51 percent of the areas to be unitized. After a public notice and hearing, IDNR can issue a unitization order if it finds that the unitization is economically feasible, adds value to the project, reasonably defines the oil or gas pool parameters, and is equitable to “all [signed and unsigned] owners of the oil and gas rights in the unit area.”

Recent legislation from Indiana, Louisiana, Montana, North Dakota, Utah, West Virginia, and Wyoming can provide insights into ways in which this issue has been addressed (see the [CCUS Law and Policy Supplement](#) for details on these state laws).


Long-term Financial Responsibility for Carbon Storage in Illinois


As part of the federal permitting process for Class VI carbon storage wells, operators are required to demonstrate financial assurance that they have sufficient financial resources in the form of qualifying third-party instruments or self-insurance to carry out geologic storage activities, including all required monitoring, site closure activities, any necessary remediation, and post-injection site care (PISC), which by default is a 50-year period after injection concludes (U.S. EPA, 2011). These requirements are intended to prevent the public from bearing the costs of abandoned geologic storage projects.

STAKEHOLDERS ASKED

What is the latest on liability passing to the state after injection has ended and the storage site has been closed?

There is no current Illinois legislation or case law that explicitly addresses long-term responsibility for carbon storage sites in Illinois. Previous state legislation in 2011 addressed long-term responsibility for CO₂ storage related only to the FutureGen Project (20 ILCS 1108). The legislation allowed the FutureGen site operator to retain all rights, title, and interest to and all liabilities associated with pre-injection CO₂ during operations and for 10 years after project completion and full permit compliance. Thereafter, all rights, title, and interest to and liability for the CO₂ would transfer to the state (20 ILCS 1108/20). The act was conditionally repealed on October 26, 2016 (20 ILCS 1108/90). No such legislation has been enacted for later projects in Illinois.

Louisiana, North Dakota, and Texas all have laws that transfer responsibility for carbon storage sites to the state after a specified time or after specific conditions or both have been met, whereas Kansas law expressly rejects state responsibility for carbon storage (see the [CCUS Law and Policy Supplement](#)  for details on these state laws).

Indiana's recently passed [CO₂ storage law](#)  provides for ownership and responsibility for a carbon storage site to transfer to the state once Indiana has issued a certificate of completion to the storage operator. To receive the certificate of completion, an operator must demonstrate that:

1. The facility is in compliance with all applicable laws governing it;
2. The storage facility is reasonably expected to retain the CO₂ stored;
3. The storage facility is stable by either showing that the stored CO₂ is essentially stationary or is unlikely to migrate outside the boundaries of the storage facility;
4. All wells, equipment, and facilities still necessary after the project's closure are in good condition and retain mechanical integrity;
5. Injection wells have been plugged;
6. All equipment and facilities not necessary for long-term monitoring have been removed;
7. Site reclamation work is completed;
8. Upon notice of intent of site closure and a site closure report having been provided to the U.S. EPA or relevant state agency, the EPA or relevant state agency has authorized the site closure.

Carbon Storage and State-owned Land in Illinois

Carbon storage operators may seek rights to store CO₂ beneath state-owned lands. Whether this is permissible, and under what terms, should be determined by Illinois legislators.

At the federal level, the U.S. Bureau of Land Management (BLM) issued [updated policy guidance about authorizing rights-of-way on BLM lands for site characterization, transportation, injection, capture, and geologic storage of CO₂](#)  (U.S. BLM, 2022). This updated guidance authorizes the use of BLM-managed pore space where surface facilities and injection wells are on private or state-owned lands or lands managed by another federal agency and requires that the rights-of-way address construction, operation, maintenance, and termination of surface facilities required to inject CO₂ for permanent geologic storage.

State Primacy

The U.S. EPA can grant primary enforcement authority or primacy to individual states, territories, or tribes. Primacy gives states the authority to administer permitting of Class VI wells as long as state-level permitting requirements and regulations are at least as stringent as the federal requirements. **Primacy may help states dovetail the federal Class VI requirements with their existing regulatory frameworks, state laws, resources, and expertise** [↗](#), and some people contend that primacy may help states issue Class VI permits more quickly. As of 2022, North Dakota and Wyoming have obtained primacy for their Class VI wells, Louisiana’s primacy application is under review at U.S. EPA, and Arizona and West Virginia are both in the “pre-application” phase seeking Class VI primacy.

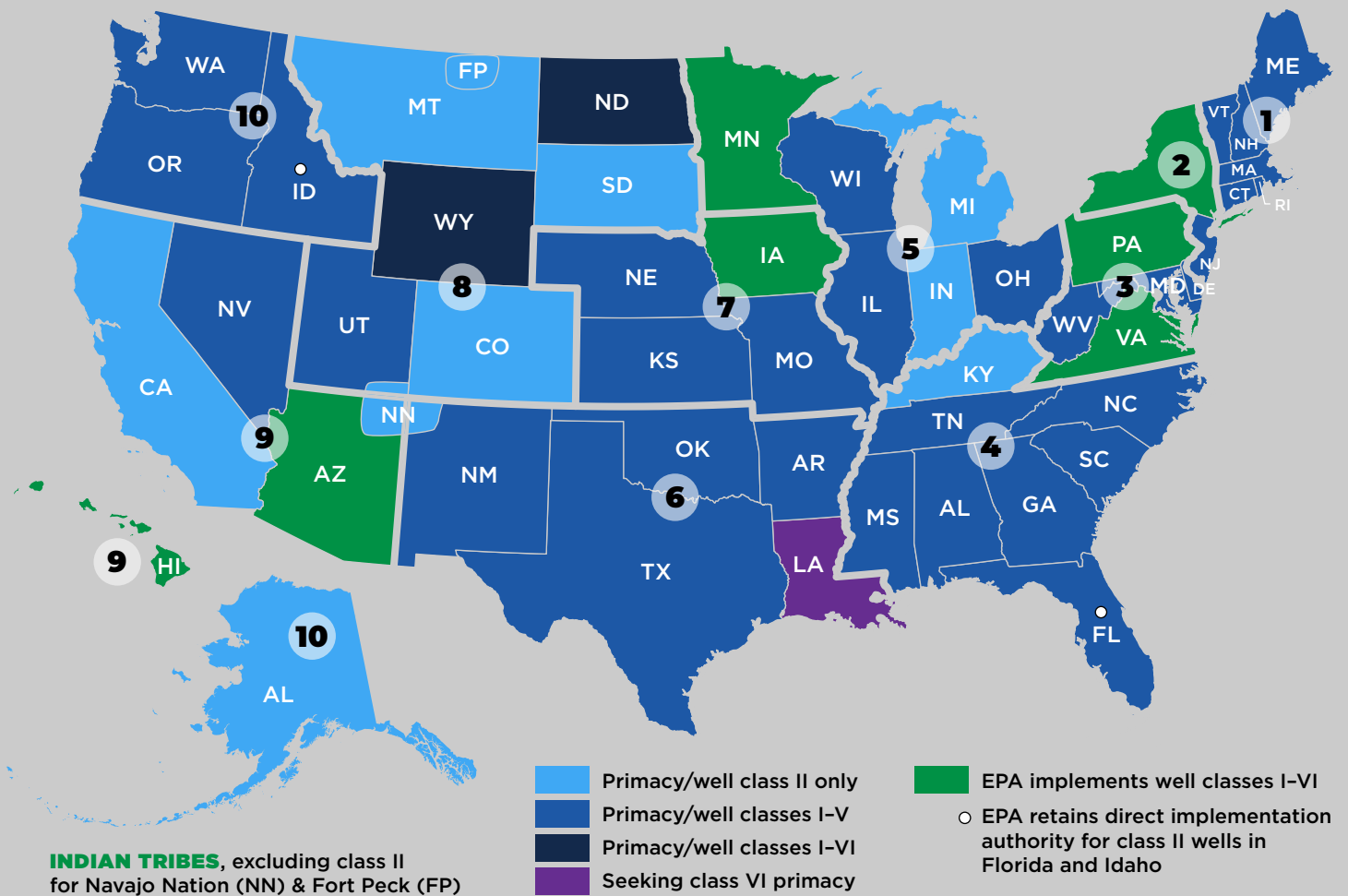


FIGURE 17. Map showing EPA regions (1-10) and primacy status by state. Primacy refers to the authority to administer permitting of Class VI injection wells. State underground injection permitting requirements and regulations must, at a minimum, be as stringent as the federal requirements.

ILLINOIS DOES NOT CURRENTLY HAVE PRIMACY FOR CLASS VI CARBON STORAGE WELLS.

However, like many states, Illinois has obtained primacy for Underground Injection Control (UIC) well classes I through V. Should Illinois believe it is in the best interest of the state to obtain state primacy, a substantial state financial investment in additional staff that have specialized expertise for review and oversight of CCUS would be needed. For example, state agency stakeholders have specifically identified the need for more permitting and monitoring resources and qualified engineers and geologists who have extensive expertise in UIC wells and modeling.

In December 2021, the [Infrastructure Investment and Jobs Act \(IIJA\)](#) authorized the U.S. EPA to grant funding to states that receive primacy for UIC Class VI wells. States can use the IIJA funding to defray expenses related to establishing and operating UIC Class VI programs. Congress has appropriated \$50 million to fund the program for fiscal years 2022 through 2026.

RECOMMENDATIONS

SUBSURFACE RIGHTS

- Clarify pore space ownership for landowner protection and for the adoption and implementation of an effective CCUS program in Illinois.
- Review existing property law and consider the development of a mechanism to combine subsurface property interests to enable large-scale projects.

PERMITTING

- Legal and regulatory frameworks should be created for the long-term stewardship and oversight of geologic storage sites.
- Encourage interagency and stakeholder discussion to determine if the state of Illinois will seek Underground Injection Control program primacy for the Class VI well class. In the event that the state of Illinois considers seeking primacy for the UIC Class VI program:
 - For all relevant state agencies, secure adequate staff and resources to ensure sufficient expertise, knowledge, and personnel availability to process permit applications promptly and ensure the safe and effective regulation of carbon sequestration.
 - In recognition of the expenses associated with securing the aforementioned staff and resources needed to establish and administer a safe and effective UIC Class VI program, consideration should be given to securing devoted Class VI program funding recently made available to states through the passage of the Infrastructure Investment and Jobs Act (H.R. 3684).

ECONOMIC IMPACT


This section addresses regional costs and benefits of commercial-scale deployment of CCUS in Illinois using four primary metrics: employment, labor income, gross regional product (value added), and output. This section also details fees and incentives, such as 45Q and 45Z tax credits, and federal funding programs, such as the Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA) Program.

PUBLIC ACT 102-0341

Economic impact, job creation, and job retention from carbon capture, utilization, and storage that both protects the environment and supports short-term and long-term economic growth

Methodologies to establish any necessary fees, costs, or offsets

Commercial-scale deployment of CCUS technology, coupled with 45Q tax incentives, has the potential to beneficially impact regional economies. Members of communities in which these technologies have been or might be implemented, elected officials, investors, and other stakeholders are interested in understanding how their development might impact employment or otherwise affect regional economies.

Industrial Economics, Incorporated  conducted an Impact Analysis for Planning (IMPLAN) economic impact analysis of CCUS in Illinois to examine particular factors such as development, employment, or other economic change in terms of output, revenue, wages, and jobs.

THE ANALYSIS PRESENTS REGIONAL IMPACT ESTIMATES BY CCUS OPERATIONAL PHASE (I.E., PRE-INJECTION, INJECTION, AND POST-INJECTION), AND INCLUDES TOTAL AS WELL AS AVERAGE ANNUAL IMPACTS.

TABLE 3. Regional economic impacts of the Illinois Basin – Decatur project (12 years).

Category	Employment	Labor Income	Value Added	Output
PRE-INJECTION PHASE (3 YEARS)				
Capture	140	\$11.1 million	\$15.6 million	\$28.6 million
Transportation	30	\$1.3 million	\$2.2 million	\$6.6 million
Storage	500	\$24.1 million	\$26.7 million	\$62.5 million
Total Effect of Pre-injection Phase	670	\$36.6 million	\$44.5 million	\$97.7 million
INJECTION PHASE (3 YEARS)				
Capture	50	\$4.9 million	\$10.6 million	\$22.2 million
Storage	200	\$17.3 million	\$20.1 million	\$33.9 million
Total Effect of Injection Phase	250	\$22.2 million	\$30.7 million	\$56.1 million
POST-INJECTION (6 YEARS)				
Storage	200	\$16.2 million	\$17.7 million	\$30.4 million
Total Effect of Post-Injection Phase	200	\$16.2 million	\$17.7 million	\$30.4 million
TOTAL, ALL PHASES (12 YEARS)				
Pre-Injection phase (~3 years)	670	\$36.6 million	\$44.5 million	\$97.7 million
Injection phase (3 years)	250	\$22.2 million	\$30.7 million	\$56.1 million
Post-Injection phase (~6 years)	200	\$16.2 million	\$17.7 million	\$30.4 million
Total Effect, All Phases (~12 years)	1,100	\$75.1 million	\$92.9 million	\$184 million
TOTAL, AVERAGE ANNUAL				
Pre-Injection phase (3-yr average)	220	\$12.2 million	\$14.8 million	\$32.6 million
Injection phase (3-yr average)	80	\$7.4 million	\$10.2 million	\$18.7 million
Post-Injection phase (6-ye average)	30	\$2.7 million	\$3.0 million	\$5.1 million
Total (12-yr average)	90	\$6.3 million	\$7.7 million	\$15.3 million

Expenditure information captures past and potential future costs to permit, construct, operate, and eventually close facilities involved with the capture, transportation, and subsurface storage of CO₂ in Illinois.

Because IMPLAN analysis depends on robust data inputs, the Prairie Research Institute (PRI) and Industrial Economics, Incorporated decided to focus on the recently completed Illinois Basin — Decatur Project (IBDP) as an example of the economic impacts derived from a CCUS project. ISGS provided data on the IBDP's expenditures for capture, transport, and storage of CO₂ through all phases of the project, from 2008 to 2021. These input expenditures of \$90.8 million generated \$172.7 million in economic impact for Illinois.

The analysis serves as an estimate of the potential regional economic benefits associated with CCUS project development in Illinois through the evaluation of two scenarios: construction and three years of operation of a small ethanol capture facility with onsite CO₂ storage (i.e., the Illinois Basin — Decatur Project (IBDP), completed in 2021); and a potential future “storage hub” scenario that includes five capture facilities that would transport captured CO₂ to a shared storage site. The hub scenario used modeled case study cost estimates developed by the U.S. Department of Energy's National Energy Technology Laboratory (U.S. DOE NETL), together with IBDP project data scaled to the size of modeled facilities.

ANALYSIS RESULTS

The outputs of the IMPLAN model include four primary metrics: employment, labor income, gross regional product (value added), and output.

- **EMPLOYMENT** reflects a mix of full-time and part-time jobs that result from additional employment demand created by a project. Employment impacts are expressed in job-years, or jobs over the course of a single year.
- **LABOR** Income captures all employment income received as part of the project-related employment demand, including wages, benefits, and proprietor income.
- **GROSS REGIONAL PRODUCT** (or value added) reflects the total value of all output or production minus the costs of intermediate outputs (value added is analogous to gross domestic product). This includes payroll, sales, excise, and property taxes.
- **ECONOMIC OUTPUT** (sales) reflects the total value of all output or production, including the costs of intermediate and final outputs.

For each of these metrics, impacts are also reported as direct, indirect, and induced effects.

- **DIRECT EFFECTS** are the production changes or expenditures that directly result from an activity or policy, in this case spending on the proposed project.
- **INDIRECT EFFECTS** are “ripple” impacts that result from changes in the output of industries that supply goods and services to industries that are directly affected.
- **INDUCED EFFECTS** are changes in household consumption arising from changes in employment and associated income that result from direct and indirect effects.

TABLE 4. Regional economic impacts of the Storage Hub Scenario (approximately 30 years).

Phase	Employment	Labor Income	Value Added	Output
PRE-INJECTION PHASE (3 YEARS)				
Capture	5,800	\$453.0 million	\$680.6 million	\$1.1 billion
Transportation	1,700	\$131.1 million	\$170.7 million	\$313.0 million
Storage	1,200	\$49.7 million	\$51.1 million	\$132.5 million
Total Effect	8,600	\$633.8 million	\$902.5 million	\$1.6 billion
INJECTION PHASE (20 YEARS)				
Capture	4,300	\$368.3 million	\$611.6 million	\$1.4 billion
Transportation	300	\$39.9 million	\$97.5 million	\$147.6 million
Storage	500	\$42.2 million	\$48.0 million	\$85.3 million
Total Effect	5,200	\$450.5 million	\$757.1 million	\$1.6 billion
POST-INJECTION PHASE (APPROXIMATELY 3 YEARS)				
Storage	600	\$53.2 million	\$55.0 million	\$95.6 million
Total Effect	600	\$53.2 million	\$55.0 million	\$95.6 million
TOTAL, ALL PHASES (10 YEARS)				
Pre-Injection (~3 years)	8,600	\$633.8 million	\$902.5 million	\$1.6 billion
Injection (20 years)	5,200	\$450.5 million	\$757.1 million	\$1.6 billion
Post-Injection (~6 years)	600	\$53.2 million	\$55.0 million	\$95.6 million
Total Effect	14,400	\$1.1 billion	\$1.7 billion	\$3.3 billion
TOTAL, AVERAGE ANNUAL				
Pre-Injection phase (3-yr average)	2,900	\$211.3 million	\$300.8 million	\$524.8 million
Injection phase (20-yr average)	260	\$22.5 million	\$37.9 million	\$79.5 million
Post-Injection phase (6-yr average)	100	\$8.9 million	\$9.2 million	\$15.9 million
Total (30-yr average)	480	\$37.9 million	\$57.2 million	\$108.7 million

Total regional economic impacts estimated for hub-related expenditures in all phases are estimated to be \$3.3 billion on output (sales) over approximately 30 years, or about \$108.7 million on average annually. Employment demand is estimated to increase by 14,400 jobs over the course of the project, or 480 jobs on average annually.

Regional economic impacts associated with expenditures for each project phase include the following.

PRE-INJECTION (PLANNING AND CONSTRUCTION) PHASE.

Estimated to be \$1.6 billion over approximately three years, or \$524.8 million annually. Employment impacts are estimated to be the highest in this phase, with an estimated increase in employment demand of 2,900 jobs per year over approximately three years.

INJECTION (OPERATIONS) PHASE. Estimated to be \$1.6 billion over 20 years, or \$79.5 million annually. Employment demand is estimated to increase by 260 jobs per year over this 20-year period.

POST-INJECTION PHASE. Estimated to be \$95.6 million over approximately six years, or \$15.9 million annually. Employment demand is estimated to increase by 100 jobs per year over approximately six years.

THIS TYPE OF ANALYSIS DOES HAVE SOME LIMITATIONS, AND IT IS RECOMMENDED THAT IMPLAN AND OTHER ECONOMIC ANALYSES BE CONDUCTED REGULARLY TO UNDERSTAND POTENTIAL IMPACTS.

- IMPLAN offers a static representation of impacts. It measures a “point in time” impact to the economy at a particular time but does not account for adjustments to the economy that may arise over time.
- IMPLAN assumes a constant relationship between inputs and outputs. It is not iterative insofar as it does not adjust its outputs according to limitations in local supplies.
- Impacts that occur outside of the defined study area “leak out” of the model. IMPLAN’s outputs are limited to the regional boundaries set at the outset of the modeling exercise. Therefore, the model cannot capture impacts that arise beyond the defined study area.

Fees and Incentives

Several states charge fees for carbon storage. Indiana, for example, has established a fee of \$.08 per ton of CO₂ stored in the state. Payments are deposited in trust to support long-term monitoring and management of carbon storage sites. Other states that use fees and penalties to support long-term monitoring include Kansas, Louisiana, Montana, North Dakota, Texas, and Wyoming.

Kansas, Montana, North Dakota, and Texas also offer some form of tax exemption to CCUS projects. Kansas, for example, exempts CCUS properties from property taxation.

California provides a credit of \$200 per ton for certain carbon capture and storage projects under its Low Carbon Fuel Standard. The credit can be claimed by carbon capture and storage projects outside of California provided that the resulting fuel is consumed in California.

Illinois Incentives

Currently, Illinois has two programs that provide incentives for the capture and storage of CO₂ from coal facilities:

- The Renewable Energy Resources and Coal Technology Development Assistance Charge, which funds the Coal Technology Develop-

ment Assistance Fund to support the capture and storage of carbon emissions produced by coal combustion as well as carbon capture and sequestration research. The end date is December 31, 2025.

- **The Clean Coal Portfolio Standard Law (P.A. 95-1027)** [↗](#) has been in effect since 2009 and provides a statewide framework for developing “clean coal” facilities that capture at least 50 percent of their total CO₂ emissions and comply with the limits for other regulated pollutants. The law requires electric utilities and suppliers in Illinois to purchase up to 5 percent of electricity from clean coal facilities and stipulates that Illinois should get 25 percent of its electricity supply from clean coal by 2025. The law also guarantees 30-year electricity purchase agreements to clean coal facilities and demand for electricity from clean coal facilities.

Federal 45Q Tax Credits

The **2008 Energy Improvement and Extension Act** [↗](#) created a tax credit under the Internal Revenue Code’s Section 45Q for any taxpaying entity that captured CO₂ at a qualified industrial or direct air capture (DAC) facility and physically or contractually ensured the geologic storage or utilization of the CO₂.

The terms of the 45Q credit have evolved over the years, most recently with the **2022 Inflation Reduction Act (IRA)** [↗](#), which:

- Applies 45Q credits to any industrial or direct air capture (DAC) facility that begins construction of CCUS equipment before Jan. 1, 2033.
- Establishes a \$17 per metric ton baseline credit for permanently stored CO₂ from qualified facilities with the credit increasing to \$85 per metric ton if wage, hour, and apprenticeship requirements are met.
- Establishes a \$36 per metric ton baseline credit for permanently sequestered CO₂ from DAC facilities with the credit increasing to \$180 per metric ton if wage, hour, and apprenticeship requirements are met.
- Reduces the amount of CO₂ that facilities must capture to take advantage of the tax credit by (1) at least 1,000 metric tons of CO₂ during a taxable year for DAC facilities; (2) at least 18,750 metric tons for electric generating facilities (EGF); and (3) at least 12,500 metric tons for other facilities. EGFs must also employ carbon capture technology capable of capturing at least 75 percent of CO₂ output.
- Allows tax-exempt CCUS developers (i.e., states, municipalities, tribes) to receive direct payment instead of 45Q credit for 12 years and non-exempt developers to receive a similar direct payment instead of a credit for the first five years.
- Revises the reduced 45Q credit for qualified CCUS projects financed by private activity bonds by the lesser of either 15 percent or the percentage of private activity bonds used for the project.
- Creates a new provision allowing owners of carbon capture equipment to make a one-time transfer of all or part of their 45Q credit to unaffiliated third parties in exchange for a cash payment.

Federal CIFIA Loan Program

The Carbon Dioxide Transportation Infrastructure Finance and Innovation (CIFIA) Program, which was established under the [Infrastructure Investment and Jobs Act \(IIJA\)](#) [↗](#) (P.L. 117-58), authorizes \$2.1 billion to the U.S. DOE through FY 2026 to fund low-interest federal loans and grants for CO₂ transportation projects including CO₂ pipeline construction (U.S DOE, 2022). Under the CIFIA Program, the U.S. DOE receives \$600 million for each of the fiscal years 2022 and 2023 and \$300 million for each of the fiscal years 2024 through 2026 or until expended (P.L. 117-58, § 41004).

THE PROGRAM IS DESIGNED TO SUPPORT CCUS AND DAC TECHNOLOGY DEPLOYMENT BY FINANCING PROJECTS THAT BUILD SHARED CO₂ TRANSPORT INFRASTRUCTURE CONSTRUCTION (U.S. DOE, 2022).

The CIFIA loans can be used for eligible project costs, development-phase activities, construction and procurement activities, acquisition of real property, capitalized interest, and associated transaction costs (P.L. 117-58, § 999 A). Also, the loans are available for up to 80 percent of anticipated eligible project costs for up to 35 years after project completion or until the end of a project's useful life, whichever is earlier (P.L. 117-58, § 999 C).

Eligible applicants can be corporations, partnerships, joint-ventures, and governmental entities or agencies (U.S DOE, 2022). Projects must be National Environmental Policy Act (NEPA)-approved (42 U.S.C. § 4321 et. seq.), creditworthy, demonstrate a reasonable prospect of repayment, and have anticipated project costs equal to or greater than \$100 million (P.L. 117-58 § 999 B). Loan priority will be given to large-capacity common-carrier infrastructure projects that have demonstrated demand, promote geographic diversity of carbon capture projects, and that are sited within or near existing pipeline corridors to minimize environmental disturbance (P.L. 117-58, § 999 G). The [CIFIA Program Guide](#) [↗](#), published by U.S. DOE in October 2022, provides more in-depth guidance on these loans.

RECOMMENDATIONS

- Retain experts who have specialized knowledge, skill, education, experience, or training in economics, finance, or tax law to:
 - Conduct additional study on a fee structure for a per-ton injection fee that supports post-closure stewardship.
 - Consider the economic opportunities to offset the cost of CCUS by using CO₂ to produce concrete, chemicals, fuels, and agricultural and other products.

TRANSPORT OF CO₂

This section addresses stakeholder concerns and safety considerations regarding CO₂ transportation in Illinois. This section also outlines federal regulation of CO₂ pipelines and the Carbon Dioxide Transportation and Sequestration Act (Public Act 97-0534) in Illinois.

PUBLIC ACT 102-0341

Public Act 102-0341 does not explicitly include transport of CO₂, but issues of whether, how, and where CO₂ should be transported are inextricably linked to the overall feasibility of CCUS. Therefore, we include a discussion of CO₂ transportation in this report.

STAKEHOLDERS ASKED

How much transportation or how many pipelines will there be?

Currently, there are more than 5,000 miles of CO₂ pipelines in the United States. Most of this transported CO₂ is used for enhanced oil recovery (EOR), but there is growing interest in using pipelines to transport CO₂ to suitable geologic storage complexes.

Commercial-scale transport of CO₂ can be done on trucks, railcars, or ships, or through pipelines.

ALTHOUGH SOME TRANSPORTATION MAY OCCUR VIA TRUCKING, IF LARGE AMOUNTS OF CO₂ ARE TO BE STORED IN ILLINOIS, PIPELINES WILL BE INVOLVED.

Federal Regulation of CO₂ Pipelines

The federal government is responsible for developing, issuing, and enforcing safety regulations for interstate and intrastate pipelines via the [Pipeline and Hazardous Materials Safety Administration \(PHMSA\)](#), a division of the U.S. Department of Transportation. Within PHMSA, the Office of Pipeline Safety (OPS) regulates the design, construction, operation, maintenance, and spill response planning for regulated pipelines. (For more background on federal pipeline law, see the [CCUS Law and Policy Supplement](#)).

In May 2022, PHMSA announced it would strengthen safety oversight by updating standards for CO₂ pipelines, including requirements related to emergency preparedness and response. PHMSA issued a nationwide [advisory bulletin](#) to pipeline operators, underscoring the need to plan for and mitigate risks related to land-movements and geohazards that pose risks to CO₂ pipeline integrity. The administration is also [conducting research solicitations](#) to strengthen CO₂ pipeline safety.

Although the PHMSA regulates CO₂ pipeline safety, it does not have statutory authority for the siting of CO₂ pipelines. The responsibility for establishing a regulatory framework for siting both interstate and intrastate CO₂ pipelines is left to the states.

Illinois Regulation of CO₂ Pipelines

In Illinois, the [Carbon Dioxide Transportation and Sequestration Act \(Public Act 97-0534\)](#) sets forth procedures for the Illinois Commerce Commission (ICC) to authorize the construction of CO₂ pipelines, including a limited eminent domain authority to acquire easements to property. The act requires that all CO₂ pipelines and related facilities in Illinois be in full compliance with federal laws and regulations governing the construction, maintenance, and operation of CO₂ pipelines. In addition, the act requires:

- Confirmation of an applicant's financial, managerial, legal, and technical qualifications to construct and operate CO₂ pipelines.

STAKEHOLDERS ASKED

When will there be regulations specifically for CO₂ pipelines?

- Completion of federal permitting requirements under the Pipeline Hazardous Materials Safety Administration (PHMSA) and for CO₂ pipeline construction with the U.S. Army Corps of Engineers (USACE).
- Completion of a state “agricultural impact mitigation agreement” with the Illinois Department of Agriculture.
- Confirmation that all proposed CO₂ pipelines are consistent with the public interest and will provide public benefits (the act expressly declares carbon transportation and storage “to be a public use and service, in the public interest, and a benefit to the welfare of Illinois and the people of Illinois because pipeline transportation is necessary for storage, enhanced oil recovery, or other carbon management purposes and thus is an essential component to compliance with required or voluntary plans to reduce CO₂ emissions...”).
- Certificates of authority to construct and operate CO₂ pipelines to contain “a limited grant of authority to take and acquire an easement in any property or interest in property for the construction, maintenance, or operation of a CO₂ pipeline to avoid unreasonable delay or economic hardship.”

Safety

In 2004, the Illinois State Geological Survey (ISGS) published a [technical report](#) that addresses potential geohazards that should be considered in the siting of CO₂ pipelines, including landslides in steeply sloped ground, seismic hazards such as liquefaction, seismic-induced landsliding, seismic wave propagation, ground shaking, and coal-mining subsidence. These potential geohazards can be avoided or mitigated through careful route selection and reconnaissance, state-of-the-art engineering, methodology, and innovative design practice. (Rostam-Abadi et al., 2004).

STAKEHOLDERS ASKED

Will the pipelines widen the area of review?

STAKEHOLDERS ASKED

How will we know if there is leakage in a pipe?

Stakeholders raised concerns about the potential for CO₂ pipelines to rupture, pointing to the incident that occurred near Satartia, Mississippi in February 2020. According to a [report on the incident published by PHMSA in May 2022](#), a CO₂ pipeline, which was also transporting hydrogen sulfide (H₂S), operated by Denbury Gulf Coast Pipelines ruptured after heavy rains resulted in a landslide, which created “excessive axial strain on a pipeline weld.” Two hundred people were evacuated, and 45 people sought medical attention; no fatalities were reported (PHMSA, 2022).

PHMSA issued a [Notice of Proposed Violation, Proposed Civil Penalty, and Proposed Compliance Order](#) (NOPV) to Denbury for multiple probable violations of federal pipeline safety regulations and proposed civil penalties of \$3,866,734. Notably, the PHMSA identified three main safety-related failures: lack of timely notification to the public; the absence of written procedures for emergency response; and failure to conduct routine inspections. PHMSA’s report found that the Satartia incident demonstrated the need for both “pipeline company awareness and mitigation efforts directed at addressing integrity threats due to changing climate, geohazards, and soil stability issues” and “improved public engagement efforts to ensure public and emergency responder awareness of nearby CO₂ pipeline and pipeline facilities and what to do if a CO₂ release occurs” (PHMSA, 2022). As a result of its findings, in May of 2022, the PHMSA issued a nationwide

STAKEHOLDERS SAID

There needs to be an educational element on pipeline and drilling.

[advisory bulletin](#) to all pipeline operators underscoring the need to plan for and mitigate risks related to land movements and geohazards and initiated new rulemaking to update CO₂ pipeline standards.

Eminent Domain

Several Illinois stakeholders have raised concerns about the potential use of eminent domain to convert private property to public use for CO₂ pipelines. In looking at other states, this is a clearly recognized concern. For example, [a poll commissioned by advocacy organization Food & Water Watch](#) found that 80 percent of Iowa voters oppose the use of eminent domain for CO₂ pipelines.

THERE IS NO FEDERAL EMINENT DOMAIN REGULATORY SCHEME FOR CO₂ PIPELINES.

However, the Carbon Dioxide Transportation and Sequestration Act (Section 20 (h) (i) (2)) requires that certificates of authority to construct and operate CO₂ pipelines contain “a limited grant of authority to take and acquire an easement in any property or interest in property for the construction, maintenance, or operation of a CO₂ pipeline” to avoid unreasonable delay or economic hardship. The Illinois Administrative Code (83 Ill. Adm. Code Part 302, §302.40) sets forth additional requirements for how the state can negotiate easements for in-state CO₂ pipeline development. For more information about other states’ eminent domain laws relating to CO₂ transportation, see the [CCUS Law and Policy Supplement](#).

RECOMMENDATIONS

Public Act 102-0341 does *not* explicitly include transport of CO₂, yet issues of whether, how, and where CO₂ should be transported are inextricably linked to the overall feasibility of CCUS. It is important to note that transport was a significant concern of stakeholders.

- Retain experts who have specialized knowledge, skill, education, experience, and training in CO₂ transportation and pipelines to investigate further.
- Identify existing infrastructure rights-of-way and suitable locations for potential CO₂ pipeline corridors to facilitate future deployment.
- Develop a regional CO₂ transport infrastructure action plan with surrounding states or join existing initiatives.
- Consider establishing a state-level siting authority that appropriately addresses the concerns of local governmental bodies.
- Incorporate federal law and regulation for transportation of CO₂ for underground carbon storage into state law and empower the appropriate agency, as a certified partner of the Pipeline and Hazardous Materials Safety Administration (PHMSA), to implement that law.

FEDERAL POLICIES AND PUBLIC-PRIVATE PARTNERSHIP POTENTIAL

This section addresses potential CCUS-related funding possibilities and partnerships at the federal level to advance CCUS research and development.

PUBLIC ACT 102-0341

Leveraging federal policies and public-private partnerships for research, design, and development to the state

The Midwest Regional Carbon Initiative, funded by the U.S. DOE, provides knowledge sharing and collaboration opportunities for public-private partnerships alongside other federal policies and programs that can also help incentivize and support CCUS projects. These policies have increased CCUS-related funding possibilities through the U.S. DOE. These and other funding sources are anticipated to continue for the next several years and may present opportunities and impacts on Illinois.

The Infrastructure Investment and Jobs Act (IIJA) [↗](#) \$12.1 billion for energy projects related to decarbonization includes several programs that support CCUS:

- **The Carbon Utilization Grant Program:** supports states, units of local government, public utilities, and agencies in procuring and using “commercial or industrial products that use or are derived from anthropogenic carbon oxides” and that “demonstrate significant net reductions in lifecycle greenhouse gas emissions compared to incumbent technologies, processes, and products.” The program is currently funded at \$300 million for each year of FY 2022 through 2026.
- **The Large-Scale CO₂ Storage Commercialization Program:** funds the development of new or expanded commercial large-scale CO₂ projects and “associated CO₂ transport infrastructure including funding for the feasibility, site characterization, permitting, and construction stages of project development.” The program is open to projects at any stage of development but prioritizes those that have “substantial CO₂ storage capacity” or that will store CO₂ from “multiple carbon capture facilities.” Projects are no longer required to demonstrate the ability to sequester at least 50 million metric tons of CO₂ over a 10-year period. The commercialization program is currently funded at \$2.5 billion for FY 2022 through 2026.
- **The Carbon Dioxide Transportation Infrastructure Finance and Innovation Program (CIFIA):** authorizes \$2.1 billion over five years for low-interest loans, loan guarantees, and grants for building CO₂ pipelines designed with excess capacity. For a detailed description of the CIFIA program, see the [CCUS Law and Policy Supplement](#) [↗](#).

The IIJA also includes provisions for Regional Direct Air Capture (DAC) Hubs for CO₂ Utilization or Sequestration, Front-end Engineering and Design (FEED) Projects, and “Clean Hydrogen.”

Regional DAC hubs are defined as a “network of direct air capture projects, potential CO₂ utilization off-takers, connective CO₂ transport infrastructure, subsurface resources, and sequestration infrastructure located within a region.”

THE REGIONAL HUBS MUST HAVE THE CAPACITY TO CAPTURE AND SEQUESTER AND/OR UTILIZE AT LEAST 1 MILLION METRIC TONS OF CO₂ FROM THE ATMOSPHERE ANNUALLY.

STAKEHOLDERS SAID

A statewide public notification process will need to be created and in place if public land is going to be used.

Federal funding priority will be given to projects that are scalable, that are in regions with existing or recently retired carbon-intensive fuel production or industrial capacity, and that have diverse geographic locations. To date, federal funding has been authorized for four regional hubs, two of which must be in “economically distressed communities in regions of the U.S. with high levels of coal, oil or natural gas resources.” Of note, the regional hubs must “to the greatest extent possible” coordinate with projects established under the CIFIA program to further leverage the federal funding. Federal appropriations in the amount of \$3.5 billion have been authorized for FY 2022 through 2026 or until expended.

Front-end engineering and design (FEED) projects for both carbon capture technologies and CO₂ transport infrastructure will be funded at \$100 million for FY 2022 through 2026.

Clean hydrogen provisions include hydrogen produced from fossil fuels with carbon capture, utilization, and storage and are intended to help accelerate research into the feasibility of clean hydrogen.

CURRENTLY, THE IIJA PROVIDES AUTHORITY TO DEVELOP FOUR CLEAN HYDROGEN HUBS WITH THE REQUIREMENT THAT AT LEAST ONE OF THE REGIONAL HUBS DEMONSTRATES THE PRODUCTION OF CLEAN HYDROGEN FROM FOSSIL FUELS.

RECOMMENDATIONS

ENERGY AND CLIMATE POLICY

- Review the approach to carbon accounting used by the U.S. EPA and the IRS in connection with 45Q or 45Z tax credits, and consideration of any modifications needed to reflect Illinois’ needs, including the adoption of greenhouse gas accounting protocols for CCUS projects.

STAKEHOLDER ENGAGEMENT AND ENVIRONMENTAL JUSTICE

This section addresses stakeholder and environmental justice concerns to be considered for the successful widescale deployment of CCUS activities in Illinois. The stakeholder feedback was collected from virtual listening sessions and written submissions [via the CCUS website](#).

PUBLIC ACT 102-0341

Development of knowledge capacity of appropriate state agencies and stakeholders

Environmental justice and stakeholder issues related to carbon capture, utilization, and storage throughout the state

Stakeholder Concerns

The following section details the wide range of stakeholder concerns, questions, opinions, and feedback that were collected via virtual listening sessions and written comments provided either through the CCUS website or sent directly to the CCUS study team. Stakeholder opinions and objectives varied significantly and represented multiple perspectives—often resulting in opposing viewpoints. This section does not reflect the views of the Prairie Research Institute, the University of Illinois, or the State of Illinois. Names of groups, individuals, and agencies have been redacted to protect the privacy of the individual or entity.

STAKEHOLDERS SAID

Stakeholders want to be informed, consulted, and included in the policy-making process for CCUS.

Public Engagement

Illinois generally follows the [federal UIC Class VI Well program rule's](#) [guidance for incorporating public participation measures](#) into state CCUS projects. However, the federal guidelines do not require owners or operators to engage with stakeholders, nor do they address the potential impacts of CO₂ pipeline placement or of increased coal mining or carbon production at industries using CCUS technologies and located in or near environmental justice communities. Challenges to public participation remain and include the lack of technical resources, transportation barriers, cultural barriers, and language barriers.

Climate Change Impacts

The issue of CCUS-related climate change impacts on nearby communities is not straightforward. On the one hand, all communities within the AoR may have a greater stake in mitigating climate change since they are more likely to be disproportionately affected by its potential impacts. On the other hand, CCUS technologies can also benefit all communities near the AoR by reducing CO₂ emissions and by potentially increasing or maintaining employment opportunities (Medvecky et al., 2014). There is also evidence that delaying CCUS technology may deter the development of other forms of climate mitigation like renewable energy (Medvecky et al., 2014; Pacala, 2004).

Various stakeholders suggested that the State should halt the transport or storage of CO₂ within state lines and direct more resources to accelerate the transition to renewable energy sources, such as wind, solar, and backup battery power. Other stakeholders favored alternative CO₂ mitigation strategies, including abandoning fossil fuels entirely in conjunction with planting native trees, restoring prairies, and protecting the rainforest.

STAKEHOLDER OPINION

Pipelines are a major concern for landowners and are likely underrepresented in the study. Stakeholders cited disruption to farmland and other properties, energy used to transport, and the overall footprint of pipelines.

Pipeline Siting and Safety

Large-scale CCUS requires scaled-up infrastructure that includes constructing new pipelines to transport the CO₂ and adapting and extending current pipelines for CO₂ transport. This raises issues of existing pipelines already located in or near communities within the area of review (AoR), where extensions and new pipelines will be located, and what laws, regulations, and monitoring criteria will be used in siting CO₂ pipelines and addressing short and long-term safety concerns (Kole, 2014).

STAKEHOLDERS EXPRESSED CONCERN THAT THE PUBLIC ACT DID NOT INCLUDE TRANSPORTATION WITHIN THE SCOPE OF THE STUDY, AND THAT THE ISSUE OF CO₂ TRANSPORTATION IN ILLINOIS WILL NOT BE GIVEN ADEQUATE ATTENTION BY THE STATE.

Property and Ownership

Stakeholders agreed that there is a need for the State to set clear guidelines regarding pore space ownership, access, and unitization, but held opposing viewpoints about those issues.

STAKEHOLDER OPINION: Carbon storage poses unnecessary and uncertain risks because pore space is not a defined area that can be controlled.

Property owners are concerned about forced amalgamation if more than 50 percent of people in a particular area agree to the development of a storage project incorporating pore space. They also expressed concern about the use of eminent domain for CO₂ storage projects. The rapid development of energy and CO₂ storage projects has caught landowners by surprise, and some are reporting project fatigue due to the number of inquiries to use their land. Landowners also have questions about who owns pore space and how surface rights relate to subsurface rights. Property concerns related to pipeline siting are detailed in the relevant sections of this report.

STAKEHOLDER OPINION: Illinois should consider clarifying pore space ownership where the surface and mineral estates have been split, which is essential for advancing CCUS projects. Illinois should set clear guidelines that allow for CCUS project development if a majority of owners of a block of land agree.

Some stakeholders suggested looking to other states' frameworks for guidance. Several states have enacted pore space ownership and use legislation, and the majority have determined that pore space ownership is vested with the surface owner.

Stakeholders also expressed the following opinions regarding pore space ownership, access, and management:

Pore space access: Ensuring there are clear mechanisms to allow for the various State-owned lands and pore space to be accessed for carbon storage will be critical to ensuring the storage potential of Illinois is fully realized.

Mechanism to enable unitization of pore space: The ability to aggregate and unitize pore space is one of the most important factors to enable at-scale CCS business development. A 60% threshold for pore space unitization is consistent with legislation passed by other states. Unitization is particularly important for Illinois, considering the regulatory certainty in neighboring states and the size of the projected CCS market.

Post-injection transfer of ownership, management, and responsibility:

Illinois may develop a legal framework for the state to accept a transfer of ownership, management, and responsibility for the CO₂ and storage facility after secure geologic storage is demonstrated. Several states such as Indiana, Louisiana, and North Dakota have enacted legislation to address this issue.

Permitting

While permitting clarity within the state is needed, stakeholders had varying perspectives about primacy at the state level. The CCUS study group section is designed to ensure that a broad spectrum of stakeholder opinions is shared with the State.

STAKEHOLDER OPINION: Federal regulatory processes are sufficient to address CCUS permitting needs.

Some stakeholders did not support the creation of a new regulatory or permitting scheme in Illinois, citing the U.S. EPA's Underground Injection Control requirements for Class VI injection wells are comprehensive as far as procedures, standards, and safeguards, especially with regards to well construction, characterization, modeling, monitoring, safety, prevention of leakage, and financial assurance. Additionally, stakeholders expressed concerns that creating an entirely new state-based permitting and regulatory scheme could impede the development of CCUS in Illinois.

“The federal Class VI permitting process is sufficient. Delaying the ability to sequester CO₂ by recommending additional and potentially contradictory permitting and/or approvals by State agencies would negatively impact the project timeline and the environmental benefits that could be achieved.”

STAKEHOLDER OPINION: Illinois should consider applying for primacy over the Class VI permitting program, but only if the State can design and implement a process that grants a Class VI permit within a shorter timeframe relative to U.S. EPA while delivering an equal assurance of safety and operational integrity.

Some stakeholders said that state primacy has given other states, such as North Dakota, a competitive advantage by having the ability to move promptly on permitting and issuing its first Class VI permits. Many industrial stakeholders emphasized that establishing predictable permitting timelines would have a significant positive impact on business development in Illinois.

STAKEHOLDER OPINION

Illinois may find itself as a less attractive investment option when other states have more flexible policies.

STAKEHOLDER CONCERNS

Stakeholders expressed concerns about the amount of water used by carbon capture projects and want water supply to be considered when evaluating the life cycle impact of CCUS projects.

Other Risk Burdens

CCUS technologies may place other risk burdens (e.g., seismicity, drinking water contamination, migration, leakage, and property devaluation) on environmental justice communities that may not have adequate resources to address related CCUS siting, monitoring, and mitigation issues. For example, communities located near CCUS injection well sites or feeder pipelines may be disproportionately exposed to high concentrations of CO₂ from natural and human causes, and

CO₂ well and pipeline construction activities may pose additional, cumulative health risks and impact property and property values, animals, and the local environment.

Several stakeholders expressed concerns that power plants with CCUS units use more energy, thereby increasing emissions of pollutants other than CO₂ and negatively impacting the air quality of the surrounding communities, while perpetuating fossil fuel use. Some stakeholders said they were fully against any form of carbon capture and sequestration that perpetuates the use of fossil fuels in any way. Others were concerned that carbon capture does not remove other pollutants associated with coal-fired power plants and noted that the solvents typically used to capture CO₂ in flue gas must be captured as hazardous waste.

Although CCUS technology captures and sequesters CO₂ generated by various industries (e.g., hydrogen and ammonia production, biomass conversion, cement processing, and iron and steel processing), it will not mitigate, and could potentially increase, co-pollutants such as fine particulate matter that may result in negative cumulative health and economic impacts on nearby communities (Page et. al., 2020). In addition, stakeholders expressed concerns about potential impacts beyond where the initial injection wells are located, crossing state boundaries (migration).

Without the appropriate infrastructure, CCUS-related employment boosts may not occur in environmental justice communities. [White House Environmental Justice Advisory Council](#) (WHEJAC) identified CCUS technologies as examples of projects that would not benefit disadvantaged and other environmental justice communities (WHEJAC, 2021). Note also that CCUS technology, from build-out to operation and through closure and post-closure, has the potential to impact environmental justice communities for long periods of time, spanning generations and necessitating the consideration of the long-term management of CO₂ technologies in and near these communities (Hansson & Bryngelsson, 2009).

Stakeholders expressed conflicting viewpoints regarding the economic impacts of CCUS.

Some stakeholders said CCUS can provide a positive economic impact in Illinois and position businesses in Illinois to be globally competitive as the energy economy shifts towards low and zero-carbon energy sources.

However, other stakeholders argue that CCUS is a questionable technology and an expensive endeavor and that public funding should be used to fund education and address public infrastructures, such as hospitals, roads, and maintenance of municipal buildings.

STAKEHOLDER OPINION

Public funding should not be used for supporting this suite of technologies and could be better used on schools and public buildings.

Environmental Justice

The [U.S. EPA](#) defines environmental justice as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies” and posits that environmental justice is achieved “when everyone enjoys: the same degree of protection from environmental

and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.”

Federal Environmental Justice Landscape

In 2021, the Biden Administration issued [Executive Order 14008](#), which established the [Justice40 Initiative](#), requiring that 40 percent of the overall benefits of certain federal investments flow to disadvantaged communities. (E.O. 14008 at page 7632).

UNDER THE INITIATIVE, FEDERAL FUNDING FOCUSES ON CERTAIN CATEGORIES OF PROJECTS, INCLUDING CLEAN ENERGY INVESTMENTS SUCH AS CARBON CAPTURE, UTILIZATION, AND STORAGE; THESE CATEGORIES ARE ALSO SUPPORTED BY PROVISIONS IN THE BIPARTISAN INFRASTRUCTURE LAW (2021) AND THE INFLATION REDUCTION ACT (2022).

Covered investments include:

- Federal assistance as defined at 2 CFR 200.1, federal grants, cooperative agreements, loans, loan guarantees, and direct spending/benefits,
- Direct payments or benefits to individuals,
- Federal procurement benefits,
- Programmatic federal staffing costs, and
- Additional federal investments under covered programs as determined by the Office of Management and Budget (OMB).

BENEFITS OF THESE FEDERAL INVESTMENTS WILL BE DELIVERED TO DISADVANTAGED COMMUNITIES THAT ARE MARGINALIZED, UNDERSERVED, AND OVERBURDENED BY POLLUTION AND ENVIRONMENTAL HAZARDS.

An initial step of the initiative requires the federal government to identify communities at risk using new tools developed by several federal agencies that employ a variety of indicators designed to identify and assess disadvantaged communities. For example, one of the indicators the federal tools use identifies vulnerable communities based on their disproportionate exposure to inhalable fine particulate matter (less than 2.5 micrometers in diameter), resulting most often from exposure

to chemical reactions in pollutants emitted by power plants, industries, and vehicles. Exposure to this kind of pollution can, among other things, contribute to increases in heart and lung disease in the community.

The U.S. EPA's [EJScreen](#), an environmental justice mapping tool first released to the public in 2015, uses environmental, demographic, and other indicators to identify locations and communities with potential environmental quality issues. EJScreen was updated in 2022 to add data about health disparities, climate change, and critical service gaps; the newest version, [EJScreen2.1](#), now includes environmental, demographic, and index data for the U.S. Virgin Islands, Guam, American Samoa, and the Northern Mariana Islands as well as “supplemental indexes” that highlight vulnerable populations disproportionately impacted by pollution using five additional factors: income, language, education, employment, and life expectancy. Federal agencies and states continue to use the tool to identify communities the U.S. EPA deems environmentally overburdened.

As of this writing, the White House Council on Environmental Quality is beta-testing an additional environmental justice mapping and screening tool, the [Climate and Economic Justice Screening Tool](#) (CEJST), which uses census data to identify communities as disadvantaged if they are above a threshold for one or more climate or environmental indicators and above a threshold for at least two socioeconomic indicators. Like the U.S. EPA's EJScreen Tool, the CEJST will allow federal agencies and states to identify and use more comprehensive data to address issues related to the health and resiliency of impacted communities as well as fill in data gaps. The U.S. DOE has responded to the objectives of the Justice40 Initiative, establishing comparable program goals, social considerations, and impact protocols.

The U.S. DOE has created a tool to analyze disadvantaged communities by calculating percentile values for several categories of indicators including fossil dependence, energy burden, environmental and climate hazards, and socio-economic vulnerabilities. Nationwide, 13,581 census tracts were identified based on these indicators and percentages of low-income residents. The U.S. DOE data are available through the [Energy Justice Dashboard](#), used by grant funding recipients for consistent comparison analysis across regions.

Illinois Environmental Justice Landscape

[Article XI of the Illinois Constitution](#) establishes that a “healthful environment” is a fundamental right of all Illinois residents, that it is the public policy of Illinois to maintain a healthful environment for the benefit of current and future generations, and that it is the duty of the General Assembly to pass laws to implement this public policy. To that end, the [Illinois Environmental Protection Act \(415 ILCS 5\)](#) defines an “environmental justice community” using demographic data from over 10,000 Illinois census block groups and using many of the same indicators in the federal [EJScreen Tool](#). Communities scoring in the top 25 percent of all census block groups are deemed environmental justice communities. The act's environmental indicators are also the same as those in the [Illinois Solar for All Program's Long-Term Renewable Resources Procurement Plan](#).

CURRENTLY THE IEPA IDENTIFIES THREE ISSUE AREAS EXPRESSLY RELATED TO ENVIRONMENTAL JUSTICE: OPEN DUMPING, COAL ASH, AND WATER EQUITY.

The Illinois Environmental Protection Agency (IEPA) [defines](#) an “area of environmental justice concern” as “a community with a low-income and/or minority population greater than twice the statewide average” and has created the Illinois [EPA EJ Start](#) mapping tool to help address and coordinate environmental justice activities across Illinois. The EJ Start tool identifies regions with high minority populations and/or low-income populations and draws from the U.S. Census Bureau’s American Community Survey five-year estimates, which are updated annually.

In 2021, Illinois’ [Energy Transition Act](#) (P.A. 102-0662) amended relevant state laws to add definitions of “environmental justice community,” “equity investment community,” and “eligible community.” The act also added two environmental justice-related provisions to the Illinois Environmental Protection Act: (1) the requirement that all electric generating units (EGUs) and large non-public greenhouse gas-emitting units located in or within 3 miles of an environmental justice community achieve zero CO₂ equivalents and co-pollutant emissions by January 1, 2030, and (2) a provision that allocates energy transition program and project funding in a way that administers “energy and justice efforts by the State.” For more detailed descriptions of Illinois laws related to environmental justice, see the [CCUS Law and Policy Supplement](#).

RECOMMENDATIONS

ENVIRONMENTAL ASSESSMENTS AND ENVIRONMENTAL JUSTICE

[Article XI of the Illinois Constitution](#) establishes that a “healthful environment” is a fundamental right of all Illinois residents and that it is the public policy of Illinois to maintain a healthful environment for the benefit of current and future generations. In order to mitigate harms and prioritize benefits, it is important to identify how locations of CCUS might impact Illinois’ population and especially affect areas of environmental justice concern and to prioritize those community voices in decision-making.

- CCUS deployment should prioritize environmental health and equity in consideration of planned CCUS activities.
- Conduct consistent energy, water equity, and supply assessments to ensure environmental protections are in place to address any public health considerations and impacts to nearby flora and fauna.

COMMUNICATION AND PUBLIC ENGAGEMENT

- Expand education and engagement for CCUS such that all stakeholders are better informed about safety, risks, benefits, planning, and management, particularly when plans are made, reviewed, and updated.

APPENDICES

APPENDIX A: REFERENCES

- Act of Aug 13, 2021, Pub. Act 102-0341, 2021 Ill. Laws, 102 (2021).** <https://www.ilga.gov/legislation/publicacts/fulltext.asp?Name=102-0341> ↗
- American National Standards Institute (ANSI). (2017).** *Geological Storage of Carbon Dioxide (ANSI Standard No. CSA Z741-2012 (R2017))*. <https://webstore.ansi.org/Standards/CSA/CSAZ7412012R2017> ↗
- American University School of International Service. (2020).** *Carbon Removal Glossary*. American University. <https://www.american.edu/sis/centers/carbon-removal/carbon-removal-glossary.cfm> ↗
- Archer Daniels Midland (ADM). (2022).** *Wolf Carbon Solutions, ADM Announce Partnership to Advance Decarbonization of Ethanol Production*. Archer Daniels Midland (ADM). <https://investors.adm.com/news/news-details/2022/Wolf-Carbon-Solutions-ADM-Announce-Partnership-to-Advance-Decarbonization-of-Ethanol-Production/default.aspx> ↗
- Ashworth, P., Bradbury, J., Wade, S., Ynke Feenstra, C. F. J., Greenberg, S., Hund, G., & Mikunda, T. (2012).** What's in Store: Lessons from Implementing CCS. *International Journal of Greenhouse Gas Control*, 9, 402–409. <https://www.sciencedirect.com/science/article/abs/pii/S1750583612001004?via%3Dihub> ↗
- Austin, A. I., Harvey, S. M., James, R. A., Medina, J., & Peyton, A. (2021, August 11).** State-Level Permitting Primacy May Boost Carbon Capture and Storage. *Pillsbury Law Alert*. <https://www.pillsburylaw.com/en/news-and-insights/state-level-permitting-primacy-carbon-capture-and-storage.html> ↗
- Barker, T. (2022, June 22).** PRI to Lead Direct Air Capture FEED study at U. S. Steel's Gary Works. *Prairie Research Institute News*. <https://blogs.illinois.edu/view/7447/1704971201> ↗
- Barker, T. (2020, November 11).** DOE Awards \$25 million to PRI for Design of Innovative Power Plant. *Prairie Research Institute News*. <https://blogs.illinois.edu/view/7447/1913312422> ↗
- Bass, R. (1998).** Evaluating Environmental Justice Under the National Environmental Policy Act. *Environmental Impact Assessment Review*, 18(1), 83–92. [https://doi.org/10.1016/S0195-9255\(97\)00065-6](https://doi.org/10.1016/S0195-9255(97)00065-6) ↗
- Bench-Scale Development of a Transformational Graphene Oxide-Based Membrane Process for Post-Combustion CO₂ Capture. (n.d.).** National Energy Technology Laboratory (NETL). Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0031598> ↗
- Beretta, I. (2012).** Some Highlights on the Concept of Environmental Justice and its Use. *E-Cadernos CES*, 17, Article 17. <https://doi.org/10.4000/eces.1135> ↗
- Berghout, N., & McCulloch, S. (2019).** *Putting CO₂ to Use: Creating Value from Emissions*. International Energy Agency. <https://www.iea.org/reports/putting-co2-to-use> ↗
- Boot, K., Vercelli, S., Mabon, L., Shackley, S., & Lombardi, S. (n.d.).** *[ECO₂ CCS Glossary]*. ECO₂. Retrieved October 20, 2022, from <https://www.eco2-project.eu/glossary.html> ↗
- Buchanan, A., & Mathieu, D. (1986).** Philosophy and Justice. In R. L. Cohen (Ed.), *Justice: Views from the Social Sciences* (pp. 11–45). Springer US. https://doi.org/10.1007/978-1-4899-3511-3_2 ↗
- Budinis, S. (2022).** *Direct Air Capture: A Key Technology for Net Zero*. International Energy Agency. <https://doi.org/10.1787/bbd20707-en> ↗
- Byrne, J. (2021).** Pond Technologies and AB Agri Partner to Allow Scalable Production of Algae from Carbon Emissions. *Feed Navigator*. <https://www.feednavigator.com/Article/2021/09/08/Pond-Technologies-and-AB-Agri-partner-to-allow-scalable-production-of-algae-from-carbon-emissions> ↗
- Byrne, J. (2022).** U.S. Team Want to Produce Algae for Feed Using Flue Gas and Wastewater. *Feed Navigator*. <https://www.feednavigator.com/Article/2022/01/18/US-team-want-to-produce-algae-for-feed-using-flue-gas-and-wastewater#> ↗
- California Air Resources Board. (n.d.).** Low Carbon Fuel Standard. California Air Resources Board. Retrieved December 5, 2022, from <https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard> ↗

- Carbon Transport & Storage Program. (n.d.).** National Energy Technology Laboratory. Retrieved October 19, 2022, from <https://netl.doe.gov/carbon-management/carbon-storage> ↗
- Carbon Utilization (CU) Using Algae to Produce Valued Bioproducts. (2020).** National Energy Technology Laboratory (NETL). <https://netl.doe.gov/sites/default/files/IG-CU-Algae-20200810.pdf> ↗
- Carbon Utilization (CU) via Conversion into Fuels and Chemicals. (2020).** National Energy Technology Laboratory (NETL). <https://netl.doe.gov/sites/default/files/IG-CU-Fuel-Chemical-20200508.pdf> ↗
- Carbon Utilization (CU) via Mineralization into Inorganic Materials. (2020).** National Energy Technology Laboratory (NETL). https://netl.doe.gov/sites/default/files/2020-07/IG-CU-Mineralization-Pathway_20200624.pdf ↗
- Carbon Utilization Research Council. (2022).** 45Q Amendment in the Inflation Reduction Act of 2022. [Carbon Utilization Research Council](https://www.carbonutilizationresearchcouncil.org/) ↗
- CO₂ Capture Project Glossary. (n.d.).** CO₂ Capture Project. Retrieved October 20, 2022, from <https://www.co2captureproject.org/glossary.html> ↗
- Collins Online English Dictionary. (n.d.).** Collins. Retrieved October 20, 2022, from <https://www.collinsdictionary.com/us/dictionary/english> ↗
- Council on Environmental Quality. (n.d.).** The White House. Retrieved October 20, 2022, from <https://www.whitehouse.gov/ceq> ↗
- Development and Bench-Scale Testing of a Novel Biphasic Solvent-Enabled Absorption Process for Post-Combustion Carbon Capture. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0031600> ↗
- Direct Air Capture-Based Carbon Dioxide Removal with United States Low-Carbon Energy and Sinks. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0032100> ↗
- EJScreen ver. 2.1. (n.d.).** U.S. Environmental Protection Agency. Retrieved October 19, 2022, from <https://ejscreen.epa.gov/mapper/> ↗
- Electrochemical CO₂ Conversion Technologies. (2021).** National Energy Technology Laboratory (NETL). <https://netl.doe.gov/sites/default/files/2021-03/IG-CU-Electrochemical-20210324.pdf> ↗
- Energy Improvement and Extension Act of 2008, H.R. 6049 (EAS) (2008).** <https://www.govinfo.gov/app/details/BILLS-110hr6049eas> ↗
- Energy Justice Dashboard. (n.d.).** U.S. Department of Energy. Retrieved October 19, 2022, from <https://energyjustice.egs.anl.gov> ↗
- Engineering Scale Design and Testing of Transformational Membrane Technology for CO₂ Capture. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://www.netl.doe.gov/project-information?p=FE0031946> ↗
- EPA Enterprise Vocabulary. (n.d.).** U.S. Environmental Protection Agency. Retrieved October 20, 2022, from https://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/enterprisevocabulary/search.do ↗
- Executive Office of the President. (2021).** *Executive Order 14008 of January 27, 2021: Tackling the Climate Crisis at Home and Abroad.* 86 FR 7619. <https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad> ↗
- FEED Study for Climeworks Direct Air Capture at a California Geothermal Facility with Long-Term Storage. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0032159> ↗
- FEED Study of CarbonCapture Inc. DAC and CarbonCure Utilization Technologies using United States Steel's Gary Works Plant Waste Heat. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0032154> ↗
- Final Risk Assessment Report for the FutureGen Project Environmental Impact Statement. (2007).** U.S. Department of Energy. <https://www.energy.gov/sites/prod/files/EIS-0394-DEIS-RiskAssessmentReport-2007.pdf> ↗
- Financial Terms Dictionary. (n.d.).** [Investopedia]. Retrieved October 20, 2022, from <https://www.investopedia.com/financial-term-dictionary-4769738> ↗
- Foresight Transitions and Carbon Removal Center (FTCRC). (n.d.).** *Carbon Removal Glossary.* <https://docs.google.com/spreadsheets/d/1jl-R37DpclvAPQENWY9TYG-5F4JS99g8UWYMX-1LyuBfY/edit#gid=818892690> ↗
- Full-Scale Feed Study for Retrofitting the Prairie State Generating Station with an 816 MWe Capture Plant Using Mitsubishi Heavy Industries of America Post-Combustion CO₂ Capture Technology. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0031841> ↗
- Greenhouse Gas Equivalencies Calculator. (n.d.).** U.S. Environmental Protection Agency. Retrieved October 19, 2022, from <https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator> ↗
- Hansson, A., & Bryngelsson, M. (2009).** Expert Opinions on Carbon Dioxide Capture and Storage—A Framing of Uncertainties and Possibili-

- ties. *China Energy Efficiency*, 37(6), 2273–2282. <https://doi.org/10.1016/j.enpol.2009.02.018> ↗
- Heartland Greenway. (n.d.)**. Heartland Greenway. Retrieved October 20, 2022, from <https://heartlandgreenway.com> ↗
- Helpful Definitions Related to Geologic Carbon Dioxide (CO₂) Sequestration. (2019)**. U.S. Geological Survey Energy Resources Program. https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/co2_helpful_definitions_handout.pdf ↗
- High Energy Systems for Transforming CO₂ to Valuable Products. (n.d.)**. National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0029787> ↗
- Illinois Basin – Decatur Project (IBDP). (n.d.)**. National Energy Technology Laboratory. Retrieved October 20, 2022, from <https://netl.doe.gov/coal/carbon-storage/atlas/mgsc/phase-III/ibdp> ↗
- [Illinois] Carbon Dioxide Transportation and Sequestration Act**, P.A. 097-0534, 220 ILCS 75/. <https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=3379&ChapterID=23> ↗
- [Illinois] Clean Coal FutureGen for Illinois Act of 2011**. 20 ILCS 1108. Retrieved October 20, 2022, from <https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=3387&ChapterID=5> ↗
- [Illinois] Clean Coal Portfolio Standard Law**, P.A. 095-1027. Retrieved October 20, 2022, from <https://www.ilga.gov/legislation/publicacts/95/095-1027.htm> ↗
- Illinois Climate and Equitable Jobs Act**, P.A. 102-0662 (2021). <https://www.ilga.gov/legislation/publicacts/102/PDF/102-0662.pdf> ↗
- Illinois Constitution Article 11: Environment. (n.d.)**. Retrieved October 19, 2022, from <https://www.ilga.gov/commission/lrb/con11.htm> ↗
- [Illinois] Energy Transition Act**, P.A. 102-662, 20 ILCS 730/ (2021). <https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=4221&ChapterID=5> ↗
- Illinois Environmental Protection Act**, 415 ILCS 5/13.7. Retrieved July 14, 2022, from <https://www.ilga.gov/legislation/ilcs/ilcs5.asp?ActID=1585&ChapterID=36> ↗
- Illinois EPA. (n.d.)**. *Environmental Justice (EJ)*. Illinois Environmental Protection Agency. Retrieved October 20, 2022, from <https://www2.illinois.gov/epa/topics/environmental-justice/Pages/default.aspx> ↗
- Illinois EPA EJ Start. (n.d.)**. Illinois Environmental Protection Agency. Retrieved October 19, 2022, from <https://illinois-epa.maps.arcgis.com/apps/webappviewer/index.html?id=f-154845da68a4a3f837cd3b880b0233c> ↗
- [Illinois] Oil and Gas Act**, 225 ILCS 725/22 et seq. <https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=1391&ChapterID=24> ↗
- [Illinois] Renewable Energy, Energy Efficiency, and Coal Resources Development Law of 1997**, 20 ILCS 687/. <https://www.ilga.gov/legislation/ilcs/ilcs5.asp?ActID=266&ChapterID=5> ↗
- [Illinois] Severed Mineral Interest Act**, 765 ILCS 515/. <https://www.ilga.gov/legislation/ilcs/ilcs3.asp?ActID=2194&ChapterID=62> ↗
- IMPLAN. (n.d.)**. IMPLAN. Retrieved October 20, 2022, from <https://implan.com> ↗
- Improving the Cost-Effectiveness of Algal CO₂ Utilization by Synergistic Integration with Power Plant and Wastewater Treatment Operations. (n.d.)**. National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0032098> ↗
- Improving the Economic Viability of Biological Utilization of Coal Power Plant CO₂ by Improved Algae Productivity and Integration with Wastewater. (n.d.)**. National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0030822> ↗
- [Indiana] Application for Certificate of Authority; Review; Public Information Meeting; Approval Procedure**, Pub. Act 163, Ind. Code § 14-39-1-4 (2022). <http://iga.in.gov/legislative/laws/2022/ic/titles/014/#14-39-1-4> ↗
- [Indiana] House Enrolled Act No. 1209**, (2022). <http://iga.in.gov/static-documents/4/c/e/2/4ce28005/HB1209.07.ENRS.pdf> ↗
- Industrial Carbon Capture from a Cement Facility Using the Cryocap FG Process. (n.d.)**. National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0032136> ↗
- Industrial Economics, Incorporated. (n.d.)**. Industrial Economics, Incorporated. Retrieved October 20, 2022, from <https://indecon.com> ↗
- Inflation Reduction Act of 2022**, Pub. L. No. 117-169 (2022). <https://www.congress.gov/bill/117th-congress/house-bill/5376> ↗
- Infrastructure Investment and Jobs Act**, Pub. L. No. 117-58 (2021). <https://www.congress.gov/117/plaws/publ58/PLAW-117publ58.pdf> ↗
- International CCU Assessment Harmonization Group Glossary. (n.d.)**. AssessCCUS. Retrieved October 20, 2022, from <https://assessccus.globalco2initiative.org/glossaries> ↗
- IPCC. (n.d.)**. *Synthesis Report of the Sixth Assessment Report*. Intergovernmental Panel on Climate Change. Retrieved October 19, 2022, from <https://www.ipcc.ch/ar6-syr> ↗
- IPCC Working Group III. (2022)**. *Climate Change 2022: Mitigation of Climate Change*. Intergovernmental Panel on Climate Change. https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf ↗

- ISO. (2017).** *Carbon Dioxide Capture, Transportation and Geological Storage—Geological Storage (ISO Standard No. 27914:217)*. International Organization for Standardization (ISO). <https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/41/64148.html> ↗
- Jackson, J. A., Mehl, J., & Neuendorf, K. K. E. (Eds.). (2005).** *Glossary of Geology* (5th ed.). American Geological Institute. <https://glossary.americangeosciences.org> ↗
- Jolley, T. (2021).** ISTC-led Team to Design Large-scale System for Direct Air Capture and Storage of Carbon Dioxide in the U.S. *Prairie Research Institute News*. <https://blogs.illinois.edu/view/7447/209089630> ↗
- Jolley, T. (2021).** Understanding Water's Role in Decarbonization. *Prairie Research Institute News*. <https://blogs.illinois.edu/view/7447/609430454> ↗
- Jones, A. C., & Lawson, A. J. (2021).** *Carbon Capture and Sequestration (CCS) in the United States* (No. R44902; Congressional Research Service Report). Congressional Research Service. <https://sgp.fas.org/crs/misc/R44902.pdf> ↗
- Justice40 Initiative. (n.d.).** The White House. Retrieved October 19, 2022, from <https://www.whitehouse.gov/environmentaljustice/justice40> ↗
- Kole, A. (2014).** Carbon Capture and Storage: How Bad Policy Is By-Passing Environmental Safeguards. *Journal of Environmental and Sustainability Law*, 20(2), 115. <https://scholarship.law.missouri.edu/jesl/vo120/iss2/5> ↗
- Korose, C., Rupp, J., & Greenberg, S. (2018).** *Policy, Regulatory, Legal, and Permitting Case Study Subtask 3.2 – Topical Report*. U.S. Department of Energy, Office of Fossil Energy. <https://www.osti.gov/biblio/1479644> ↗
- Kusmierczak, J. (2020).** A Primer on Mineral Interests in Illinois Real Estate. *Attorneys' Title Guaranty Fund, Inc.* <https://www.atgf.com/tools-publications/pubs/primer-mineral-interests-illinois-real-estate> ↗
- LanzaTech. (2021).** First Fabric from Recycled Carbon Emissions. *Innovation in Textiles*. <https://www.innovationintextiles.com/first-fabric-from-recycled-carbon-emissions> ↗
- Large Pilot Testing of Linde-BASF Advanced Post-Combustion Carbon Dioxide Capture Technology at a Coal-Fired Power Plant. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0031581> ↗
- Lebling, K., Leslie-Bole, H., Byrum, Z., & Bridgwater, L. (2022, May 2).** 6 Things to Know About Direct Air Capture. *World Resources Institute*. <https://www.wri.org/insights/direct-air-capture-resource-considerations-and-costs-carbon-removal> ↗
- Lux Research. (2016).** *Global Roadmap for Implementing CO₂ Utilization*. Global CO₂ Initiative. <https://deepblue.lib.umich.edu/handle/2027.42/150624> ↗
- Lux Research. (2018).** *Global Roadmap Study of CO₂U Technologies*. Global CO₂ Initiative. <http://deepblue.lib.umich.edu/handle/2027.42/146529> ↗
- McCulloch, S., Gül, T., Remme, U., Bains, P., Baylin-Stern, A., Berghout, N., Budinis, S., Levi, P., Malischek, R., Morgan, T., & Xu, D. (2020).** *Special Report on Carbon Capture Utilisation and Storage: CCUS in Clean Energy Transitions*. International Energy Agency. <https://www.iea.org/reports/ccus-in-clean-energy-transitions> ↗
- McIntosh, A., & Pontius, J. (2017).** Air Quality and Atmospheric Science. In A. McIntosh & J. Pontius (Eds.), *Science and the Global Environment* (pp. 255–359). Elsevier. <https://doi.org/10.1016/B978-0-12-801712-8.00003-2> ↗
- Medvecky, F., Lacey, J., & Ashworth, P. (2014).** Examining the Role of Carbon Capture and Storage Through an Ethical Lens. *Science and Engineering Ethics*, 20(4), 1111–1128. <https://doi.org/10.1007/s11948-013-9474-z> ↗
- Nano Engineered Catalyst Supported on Ceramic Hollow Fibers for the Utilization of CO₂ in Dry Reforming to Produce Syngas. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0029760> ↗
- National Carbon Capture Center. (n.d.).** National Carbon Capture Center. Retrieved October 19, 2022, from <https://www.nationalcarboncapturecenter.com> ↗
- National Energy Technology Laboratory (NETL). (n.d.).** *Carbon Conversion Program*. National Energy Technology Laboratory (NETL). Retrieved November 16, 2022, from <https://netl.doe.gov/carbon-management/carbon-conversion> ↗
- National Energy Technology Laboratory (NETL). (n.d.).** *CarbonSAFE Initiative*. Retrieved July 14, 2022, from <https://netl.doe.gov/carbon-management/carbon-storage/carbonsafe> ↗
- National Energy Technology Laboratory (NETL). (2012).** *The United States 2012 Carbon Utilization and Storage Atlas* (4th ed.) (DOE-SSEB-42590-119). U.S. Department of Energy National Energy Technology Laboratory. <https://doi.org/10.2172/1814016> ↗
- National Energy Technology Laboratory (NETL). (2015).** *Carbon Storage Atlas* (5th ed.) (DOE/NETL-2015/1709). U.S. Department of Energy National Energy Technology Laboratory. <https://www.netl.doe.gov/sites/default/files/2018-10/ATLAS-V-2015.pdf> ↗

- National Energy Technology Laboratory (NETL). (2022).** *NETL CO₂U LCA Guidance Toolkit*. National Energy Technology Laboratory, Carbon Dioxide Utilization. <https://netl.doe.gov/LCA/CO2U>
- National Environmental Policy Act of 1969**, 42 U.S.C. 4321 et seq. <https://www.govinfo.gov/app/details/USCODE-2020-title42/USCODE-2020-title42-chap55>
- Navigator Heartland Greenway LLC's Application for Certificate of Authority. (2022).** Illinois Commerce Commission EDOCKET. <https://www.icc.illinois.gov/docket/P2022-0497/documents/326466>
- NETL Project Information [database]. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/projects/project-landing-page-list.aspx>
- NETL Project Partner Develops Transformational Carbon Capture Technology Based on Mixed Salts. (2022).** *National Energy Technology Laboratory*. <https://netl.doe.gov/node/11496>
- Net-Zero America. (n.d.).** Net-Zero America. Retrieved October 19, 2022, from <https://netzeroamerica.princeton.edu>
- New Poll Finds Iowa Voters Overwhelmingly Oppose Eminent Domain for Carbon Pipelines. (2022).** *Food & Water Action*. <https://www.foodandwateraction.org/food/new-poll-finds-iowa-voters-overwhelmingly-oppose-eminent-domain-for-carbon-pipelines>
- O'Brien, K.C. (2022).** *Full-Scale Feed Study for Retrofitting the Prairie State Generating Station with an 816 MWe Capture Plant Using Mitsubishi Heavy Industries of America Post-Combustion CO₂ Capture Technology*. National Energy Technology Laboratory. <https://hdl.handle.net/2142/113487>
- Page, B., Turan, G., & Zapantis, A. (2020).** *Global Status of CCS 2019: Targeting Climate Change*. Global CCS Institute. https://www.globalccsinstitute.com/wp-content/uploads/2019/12/GCC_GLOBAL_STATUS_REPORT_2019.pdf
- Pacala, S., & Socolow, R. (2004).** Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. *Science*, 305(5686), 968–972. <https://doi.org/10.1126/science.1100103>
- Penn Program on Regulation. (2022).** *Voluntary Codes and Standards—Teaching Resources for Law and Public Policy Courses*. (n.d.). Penn Program on Regulation. Retrieved October 20, 2022, from <https://pennreg.org/codes-standards>
- PHMSA. (2019).** *Pipeline Enforcement Guidance*. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration. <https://www.phmsa.dot.gov/pipeline/enforcement/enforcement-program-0>
- PHMSA. (2022a).** *Failure Investigation Report—Denbury Gulf Coast Pipelines, LLC – Pipeline Rupture/ Natural Force Damage*. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration. <https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2022-05/Failure%20Investigation%20Report%20-%20Denbury%20Gulf%20Coast%20Pipeline.pdf>
- PHMSA. (2022b).** *Competitive Academic Agreement Program (CAAP)*. Grants.Gov. <https://www.grants.gov/web/grants/view-opportunity.html?oppld=338415>
- PHMSA. (2022c).** *Notice of Proposed Violation, Proposed Civil Penalty and Proposed Compliance Order to Denbury Gulf Coast Pipeline*. Pipeline and Hazardous Materials Safety Administration. <https://www.phmsa.dot.gov/news/phmsa-notice-proposed-violation-proposed-civil-penalty-and-proposed-compliance-order-denbury>
- PHMSA. (2022d).** Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards. *Federal Register*, 87 FR 33576. <https://www.federalregister.gov/documents/2022/06/02/2022-11791/pipeline-safety-potential-for-damage-to-pipeline-facilities-caused-by-earth-movement-and-other>
- Pilot Test of a Nanoporous, Super-Hydrophobic Membrane Contactor Process for Post-Combustion Carbon Dioxide (CO₂) Capture. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0012829>
- Pipeline and Hazardous Materials Safety Administration (PHMSA). (n.d.).** Retrieved September 13, 2022, from <https://www.phmsa.dot.gov>
- Pipeline Safety Regulations. (n.d.).** U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration. Retrieved June 23, 2022, from <https://primis.phmsa.dot.gov/comm/SafetyStandards.htm?nocache=1393>
- Point Source Carbon Capture Program. (n.d.).** National Energy Technology Laboratory. Retrieved October 20, 2022, from <https://netl.doe.gov/carbon-management/carbon-capture>
- PRI News (2021).** DOE Awards \$47 Million to PRI and Collaborators for Carbon Capture Project. *Prairie Research Institute News*. <https://blogs.illinois.edu/view/7447/1372195278>
- Regional Carbon Sequestration Partnership (RCSP). (n.d.).** National Energy Technology Laboratory. Retrieved October 20, 2022, from <https://www.netl.doe.gov/carbon-management/carbon-storage/RCSP>
- Reiner, D. M., & Nuttall, W. J. (2011).** Public Acceptance of Geological Disposal of Carbon Dioxide

- and Radioactive Waste: Similarities and Differences. In F. L. Toth (Ed.), *Geological Disposal of Carbon Dioxide and Radioactive Waste: A Comparative Assessment* (pp. 295–315). Springer Netherlands. https://doi.org/10.1007/978-90-481-8712-6_10 ↗
- Rodrigues, H. (2021, September 13).** Carbon Capture & Utilization Can Enable Low-Carbon Concrete Production. *IDTechEx*. <https://www.idtechex.com/en/research-article/carbon-capture-and-utilization-can-enable-low-carbon-concrete-production/24692> ↗
- Rostam-Abadi, M., Chen, S. S., Lu, Y., Nyman, D., Dracos, J. S., & Varagani, R. (2004).** *Carbon Dioxide Capture and Transportation Options in the Illinois Basin*. Illinois State Geological Survey. <https://doi.org/10.2172/896976> ↗
- ROTA-CAP: An Intensified Carbon Capture System Using Rotating Packed Beds. (n.d.).** National Energy Technology Laboratory. Retrieved November 10, 2022, from <https://netl.doe.gov/project-information?p=FE0031630> ↗
- Sheats, N. (2016).** Achieving Emissions Reductions for Environmental Justice Communities through Climate Change Mitigation Policy. *William & Mary Environmental Law and Policy Review*, 41, 377. <https://heinonline.org/HOL/Page?handle=hein.journals/wmelpr41&id=399&div=&collection=> ↗
- Sheppard, L. (2022).** Technology to Absorb CO₂ at Power Plants Is Promising. *Prairie Research Institute News*. <https://blogs.illinois.edu/view/7447/987080746> ↗
- Sick, V., Stokes, G., & Mason, F. (2022).** *Implementing CO₂ Capture and Utilization at Scale and Speed: The Path to Achieving Its Potential*. University of Michigan Global CO₂ Initiative. <https://hdl.handle.net/2027.42/174095> ↗
- Sorghan, M., & Anchondo, C. (2022).** Are CO₂ pipelines safe? *E&E News*. <https://www.eenews.net/articles/are-co2-pipelines-safe> ↗
- Turan, G., & Zapantis, A. (2022).** *Global Status of CCS 2021: CCS Accelerating to Net Zero*. Global CCS Institute. https://www.globalccsinstitute.com/wp-content/uploads/2021/10/2021-Global-Status-of-CCS-Report_Global_CCS_Institute.pdf ↗
- U.S. Army Corps of Engineers. (2001).** *Glossary of Economic Impact Terms*. <https://corpslakes.erdc.dren.mil/employees/economic/glossary.cfm> ↗
- U.S. BLM. (2022).** *National Policy for the Right-of-Way Authorizations Necessary for Site Characterization, Capture, Transportation, Injection, and Permanent Geologic Sequestration of Carbon Dioxide in Connection with Carbon Sequestration Projects* (IM 2022-041; Instruction Memorandum). U.S. Bureau of Land Management (U.S. BLM). <https://www.blm.gov/policy/im-2022-041> ↗
- U.S. Department of Energy Announces Investment to Further Develop Carbon Capture Technology via FEED Study. (n.d.).** *Holcim US*. Retrieved October 20, 2022, from <https://www.holcim.us/further-develop-carbon-capture-technology> ↗
- U.S. DOE. (n.d.-a).** *Carbon Capture, Utilization & Storage*. U.S. Department of Energy. Retrieved November 7, 2022, from <https://www.energy.gov/carbon-capture-utilization-storage> ↗
- U.S. DOE. (n.d.-b).** *Catalytic Conversion Pathway*. Retrieved July 14, 2022, from <https://www.energy.gov/fecm/catalytic-conversion-pathway> ↗
- U.S. DOE. (2022).** *CIFIA Program Guide: CIFIA Loans for Carbon Dioxide Transportation Infrastructure*. U.S. Department of Energy, Office of Fossil Energy and Carbon Management, Loan Programs Office. https://www.energy.gov/sites/default/files/2022-10/LPO_CIFIA_Guidance_Document_FINAL_2022.10.05_0.pdf ↗
- U.S. DOE Carbon Storage Program. (2017).** *Best Practices Manuals*. National Energy Technology Laboratory. <https://www.netl.doe.gov/carbon-management/carbon-storage/strategic-program-support/best-practices-manuals> ↗
- U.S. DOE, Office of Fossil Energy and Carbon Management. (n.d.).** *Carbon Mineralization Pathway*. Retrieved July 14, 2022, from <https://www.energy.gov/fecm/carbon-mineralization-pathway> ↗
- U.S. DOE Office of Fossil Energy and Carbon Management. (n.d.-a).** *Carbon Uptake Pathway*. Retrieved July 14, 2022, from <https://www.energy.gov/fecm/carbon-uptake-pathway> ↗
- U.S. DOE Office of Fossil Energy and Carbon Management. (n.d.-b).** *Carbon Conversion*. Retrieved July 14, 2022, from <https://www.energy.gov/fecm/carbon-conversion> ↗
- U.S. EPA. (n.d.-a).** *Class I Industrial and Municipal Waste Disposal Wells*. Retrieved July 14, 2022, from <https://www.epa.gov/uic/class-i-industrial-and-municipal-waste-disposal-wells> ↗
- U.S. EPA. (n.d.-b).** *Class II Oil and Gas Related Injection Wells*. Retrieved July 14, 2022, from <https://www.epa.gov/uic/class-ii-oil-and-gas-related-injection-wells> ↗
- U.S. EPA. (n.d.-c).** *Class III Injection Wells for Solution Mining*. Retrieved July 14, 2022, from <https://www.epa.gov/uic/class-iii-injection-wells-solution-mining> ↗
- U.S. EPA. (n.d.-d).** *Class IV Shallow Hazardous and Radioactive Injection Wells*. Retrieved July 14, 2022, from <https://www.epa.gov/uic/class-iv-shallow-hazardous-and-radioactive-injection-wells> ↗
- U.S. EPA. (n.d.-e).** *Class V Wells for Injection of Non-Hazardous Fluids into or Above Underground Sources of Drinking Water*. Retrieved July

- 14, 2022, from <https://www.epa.gov/uic/class-v-wells-injection-non-hazardous-fluids-or-above-underground-sources-drinking-water> ↗
- U.S. EPA. (n.d.-f).** *Class VI Wells used for Geologic Sequestration of Carbon Dioxide*. Retrieved July 14, 2022, from <https://www.epa.gov/uic/class-vi-wells-used-geologic-sequestration-carbon-dioxide> ↗
- U.S. EPA. (n.d.-g).** *Environmental Justice*. Retrieved July 14, 2022, from <https://www.epa.gov/environmentaljustice> ↗
- U.S. EPA. (2021).** *2021 Greenhouse Gas Emissions from Large Facilities* [data set]. Facility Level Information on Greenhouse Gases Tool (FLIGHT). <https://ghgdata.epa.gov/ghgp/main.do> ↗
- U.S. EPA. (2022).** *Using GHG Inventory and GHGRP Data*. U.S. Environmental Protection Agency. https://cfpub.epa.gov/ghgdata/inventoryexplorer/data_explorer_flight.html ↗
- U.S. EPA Office of Water. (2011a).** *Geologic Sequestration of Carbon Dioxide – UIC: Quick Reference Guide: Additional Considerations for UIC Program Directors on the Public Participation Requirements for Class VI Injection Wells* (EPA 816-R-11-001). U.S. Environmental Protection Agency, Office of Water. https://www.epa.gov/sites/default/files/2015-07/documents/uic-quick-reference-guide_public-participation_final-508.pdf ↗
- U.S. EPA Office of Water. (2011b).** *Geologic Sequestration of Carbon Dioxide – UIC: Quick Reference Guide: Additional Tools for UIC Program Directors Incorporating Environmental Justice Considerations into the Class VI Injection Well Permitting Process* (EPA 816-R-11-002). U.S. Environmental Protection Agency, Office of Water. <https://www.epa.gov/sites/default/files/2015-07/documents/epa816r11002.pdf> ↗
- U.S. EPA Office of Water. (2011c).** *Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Financial Responsibility Guidance* (EPA 816-R-11-005). U.S. Environmental Protection Agency. <https://www.epa.gov/sites/default/files/2015-06/documents/uicfinancialresponsibilityguidancefinal072011v.pdf> ↗
- U.S. EPA Office of Water. (2016).** *Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance* (EPA 816-R-16-006). U.S. Environmental Protection Agency, Office of Water. https://www.epa.gov/sites/default/files/2016-12/documents/uic_program_class_vi_well_plugging_post-injection_site_care_and_site_closure_guidance.pdf ↗
- U.S. EPA Office of Water. (2018).** *Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Imple-*
- mentation Manual for UIC Program Directors* (EPA 816-R-18-001). U.S. Environmental Protection Agency, Office of Water. https://www.epa.gov/sites/default/files/2018-01/documents/implementation_manual_508_010318.pdf ↗
- U. S. GAO. (2022).** *Decarbonization: Status, Challenges, and Policy Options for Carbon Capture, Utilization, and Storage* (GAO-22-105274). U.S. Government Accountability Office. <https://www.gao.gov/products/gao-22-105274> ↗
- U.S. Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team. (2013).** *National Assessment of Geologic Carbon Dioxide Storage Resources—Results* (Circular No. 1386, Version 1.1). U.S. Geological Survey. <https://pubs.usgs.gov/circ/1386/pdf/circular1386.pdf> ↗
- Van Voorhees, B., Greenberg, S., & Whittaker, S. (2021).** *Observations on Class VI Permitting: Lessons Learned and Guidance Available* (No. 9; Special Report). Illinois State Geological Survey. <http://hdl.handle.net/2142/109915> ↗
- W.E. Upjohn Institute for Employment Research. (n.d.).** *Economic Impact Studies*. Upjohn Institute. Retrieved November 29, 2022, from <https://www.upjohn.org/services/regional-and-economic-planning/economic-impact-studies> ↗
- What Is Carbon Sequestration? (n.d.).** U.S. Geological Survey. Retrieved October 19, 2022, from <https://www.usgs.gov/faqs/what-carbon-sequestration> ↗
- White House Council on Environmental Quality. (n.d.).** *Climate and Economic Justice Screening Tool*. Climate and Economic Justice Screening Tool. Retrieved September 14, 2022, from <https://screeningtool.geoplatform.gov> ↗
- White House Council on Environmental Quality. (2021).** *Council on Environmental Quality Report to Congress on Carbon Capture, Utilization, and Sequestration*. White House Council on Environmental Quality. <https://www.whitehouse.gov/wp-content/uploads/2021/06/CEQ-CCUS-Permitting-Report.pdf> ↗
- White House Environmental Justice Advisory Council (WHEJAC). (2021).** *Final Recommendations: Justice40 Climate and Economic Justice Screening Tool & Executive Order 12898 Revisions*. White House Environmental Justice Advisory Council. <https://www.epa.gov/sites/default/files/2021-05/documents/whiteh2.pdf> ↗
- Whitmarsh, L., Xenias, D., & Jones, C. R. (2019).** Framing Effects on Public Support for Carbon Capture and Storage. *Palgrave Communications*, 5(1), Article 1. <https://doi.org/10.1057/s41599-019-0217-x> ↗
- Young, S., Mallory, B., & McCarthy, G. (2021).** The Path to Achieving Justice40. *The White House*. <https://www.whitehouse.gov/omb/briefing-room/2021/07/20/the-path-to-achieving-justice40> ↗

APPENDIX B: GLOSSARY

45Q tax credit (45Q): Section of the Internal Revenue Code that provides a progressive production tax credit for carbon capture and storage. (CDR)

Absorption: The process by which one substance, such as a solid or liquid, takes up another substance, such as a liquid or gas, through minute pores or spaces between its molecules. (ECO)

Adsorption: The process by which a material attracts carbon dioxide to its surface so it can be captured and/or stored. (ECO)

Amines: Derivatives of ammonia used as solvents in post-combustion CO₂ capture process to absorb carbon dioxide from the emissions gas stream. (ECO)

Area of review: The region surrounding a geologic sequestration project where underground sources of drinking water may be endangered by the injection activity. (EPA via the Code of Federal Regulation)

Aquifer: A body of rock that contains sufficient saturated permeable material to conduct groundwater and to yield significant quantities of water to wells and springs. (GEO)

Caprock: A hard impervious rock or stratum of rock above another layer, often oil or gas bearing. (GEO)

Carbon capture: Includes any process for capturing carbon dioxide, whether from the atmosphere or from a smokestack or other concentrated source of carbon dioxide emissions. (AU)

Carbon capture, utilization, and storage (CCUS): A process that captures carbon dioxide emissions from sources like coal-fired power plants and either reuses or stores it so it will not enter the atmosphere. (U.S. DOE)

Carbon dioxide (CO₂): A naturally occurring compound which is a gas at surface atmosphere and pressure conditions. CO₂ is also a by-product

SOURCES

[American University Carbon Removal Glossary](#) (AU)

[Carbon Removal Glossary \(Foresight Transitions and Carbon Removal Center\)](#) (FTCRC)

[CDR Primer](#) (CDR)

[CO₂ Capture Project Glossary](#) (CCP)

[Collins English Dictionary](#) (COL)

[DOE Carbon Capture, Utilization, and Storage](#) (DOE)

[ECO₂ CCS Glossary](#) (ECO)

[Glossary of Geology](#) (GEO)

[International CCU Assessment Harmonization Group Glossary \(Assess CCUS\)](#) (ICCU)

[Investopedia Financial Term Dictionary](#) (INV)

[ISO 27914:2017](#) (ISO)

[Law Insider Legal Dictionary](#) (LAW)

[U.S. Army Corps of Engineers Glossary of Economic Impact Terms](#) (U.S. ACE)

[U.S. Environmental Protection Agency Enterprise Vocabulary](#) (EPA)

[USGS Helpful Definitions Related to Geologic Carbon Dioxide \(CO₂\) Sequestration](#) (USGS)

[Industrial Economics, Incorporated](#) (IE)

of burning fossil fuels (such as oil, gas, and coal), of burning biomass, of land-use changes, and of industrial processes (e.g., ethanol or cement production).

Carbon dioxide removal (CDR): see *carbon removal*

Carbon removal: Activities that remove CO₂ from the atmosphere and durably store it in geological, terrestrial, or in products. CDR includes enhancement of biological or geochemical sinks and direct air capture (DAC) and storage but excludes natural CO₂ uptake not directly caused by human intervention. (CDR)

Critical point: The temperature and pressure point above which carbon dioxide gas and liquid phases cannot exist as separate phases. (ECO)

Deep saline formation: Porous rock formation whose porosity is filled with brine. (CDR)

Direct air capture (DAC): A chemical process that removes carbon dioxide from ambient air. When paired with carbon storage strategies, sometimes referred to as direct air carbon capture and storage (DACCS). (CDR)

Economic impact analysis: Examines the effects of an event or activity on development, employment, or other economic change in terms of output, revenue, wages, and jobs. (IE)

Enhanced oil recovery (EOR): Injection of supercritical carbon dioxide into oil reservoirs for the purpose of increasing the amount of oil recovered beyond primary (conventional) extraction. (CDR)

Environmental justice: The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. (EPA)

Equity: The principle of fairness in access to opportunities, power-sharing, and burden-sharing. Equity is crucial to determining how to deploy strategies to address climate change — including CDR — that minimize harm to marginalized people and frontline communities. (CDR) See also: *environmental justice*

Financial assurance: Refers to financial coverage that provides remuneration for an event that is certain to happen. Assurance is similar to insurance, with the terms often used interchangeably. However, insurance refers to coverage over a limited time, whereas assurance applies to persistent coverage for extended periods. (INV)

Financial responsibility: Statutorily required financial ability to satisfy liability as required under state and federal laws. (LAW)

Geologic formation: A body of rock having a consistent set of physical characteristics that distinguish it from adjacent bodies of rock. This body of rock must be distinctive enough to be identifiable, and thick and extensive enough to be plotted on geological maps. (CDR)

Geological storage: Underground storage of CO₂, for instance in depleted oil and gas reservoirs, saline formations, or deep coal beds. (FTCRC)

Geophone: An electronic receiver designed to pick up seismic vibrations transmitted through rock, ice, etc. (COL)

IMPLAN: A computer-based, input-output modeling system. With IMPLAN, one can estimate I-O models of up to 528 sectors for any region consisting of one or more counties. IMPLAN includes procedures for generating multipliers and estimating impacts by applying final demand changes to the model. (U.S. ACE)

Liability: Broadly, this is any legally enforceable obligation to another party (e.g., legal responsibility, duty, or obligation). This liability may arise from contracts either expressed or implied or in consequence of torts committed. (EPA)

Life cycle assessment (LCA): Tool that can be used to assess the environmental impacts of a product, process, or service from design to disposal i.e., across its entire lifecycle. The impacts on the environment may be beneficial or adverse. These impacts are sometimes referred to as the “environmental footprint” of a product or service. (ECO)

Low-carbon concrete: Altering the constituents, the manufacture, or the recycling method of concrete to increase its storage of CO₂. (FTCRC)

Mineral estate: An estate in or ownership of all or part of the minerals under a specified tract of land. (LAW)

Mitigation: A human intervention to reduce risk and the human impact on the climate system. It includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks. (EPA)

Permeability: Ability of porous and fractured material to allow fluids to flow through it. In CCS, it refers to the ability of a porous rock, such as

sandstone, which acts like a container to allow the injected CO₂ to fill the tiny spaces between grains of the rock (see **pore space**) (ECO)

Point source: A stationary location or fixed facility from which carbon dioxide is discharged or emitted or any single, identifiable discharge point of pollution, such as a pipe, ditch, or smokestack. (EPA)

Pore space: Space between rock or sediment grains that can contain fluids. (CCP)

Porosity: The part of a rock that is occupied by voids or pores. Pores can be connected by passages that allow for fluid flow or isolated and inaccessible to fluid flow. Porosity is typically reported as a volume, fraction, or percentage of the rock. (USGS)

Post-combustion capture: Separating carbon dioxide from other waste gases after a fuel is burned. (ECO)

Primacy: Primary enforcement authority. (LAW)

Reservoir: A subsurface body of rock with the **porosity** and **permeability** to store and transmit fluids. (ECO)

Risk assessment: Evaluation of the risk to human health or the environment from a hazard. Risk assessments may look at either existing hazards or potential hazards. (EPA)

Sequestration: See **storage**

Solvent: A substance used to dissolve another substance. (EPA)

Sorbent: A solid that is used to **absorb** (absorbent) or **adsorb** (adsorbent) a given liquid or gas. For example, solid sorbents for **direct air carbon capture** are typically **amine** grafted solids which adsorb carbon dioxide on their surfaces. (CDR)

Storage: The final stage of the carbon removal process, in which carbon reaches a reservoir where it is held for an extended period of time. (FTCRC)

Storage site: An underground rock formation that can store carbon dioxide; commonly this is deep sedimentary, *porous* rock, where there are tiny spaces (**pore space**) between the rock grains for the carbon dioxide. (ECO)

Storage complex: Subsurface geological system extending vertically to comprise **storage unit(s)** and identified seal(s) and extending laterally to the defined limits of the CO₂ storage project. (ISO)

Storage unit: Geological stratum (or strata) into which CO₂ is injected for the purpose of storage. (ISO)

Supercritical fluid: Fluid at a temperature and pressure at which there is no difference between liquid and gas. (COL)

Transportation, CO₂: The process of moving captured CO₂ by truck, ship, or through a pipeline from its source to a suitable storage site. (FTCRC)