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Carbon Capture & Storage in Power Generation

WHITEPAPER

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Why CCS Matters

Decarbonizing U.S. Power Plants

The electric power industry in the United States remains a significant source of greenhouse gas emissions. In 2022, it contributed about 25 percent of the country's total greenhouse gases, making it the largest stationary emitter nationwide. Figures for 2024 are not yet finalized, but similar shares are expected.

Although emissions from power plants have decreased over the past decade, the change has mainly been due to fuel switching—from coal to natural gas—and gradual efficiency improvements. Still, more than half of U.S. electricity generation continues to come from fossil fuels, highlighting that even with widespread use of renewables and efficiency gains, some CO_2 emissions will remain unless carbon capture technologies are deployed at a large scale. Achieving national decarbonization goals—including reducing power sector emissions to the Administration's target of a carbon-pollution-free power sector by 2035—requires strategies that go beyond simply increasing wind, solar, and storage.

Carbon Capture and Storage (CCS) and its broader application, Carbon Capture Utilization and Storage (CCUS), offer tools to significantly reduce power plant emissions from operating fossil fuel assets. These technologies involve capturing CO_2 before it exits the plant stack, compressing it, and then storing it deep underground or using it in commercial processes. CCS and CCUS are not substitutes for renewable energy; instead, they support clean power from existing infrastructure, which is essential for maintaining reliability and grid stability in scenarios with high renewable energy integration.

Federal policy has recently intensified the push for CCS adoption. New regulations finalized in 2024 impose strict emissions standards on coal-fired power plants planning to operate on or after January 1, 2039, as well as on new baseload natural gas turbines. These rules essentially mandate a reduction in CO_2 emissions by about ninety percent or the retirement of non-compliant assets. In practice, using coal and gas generation combined with CCS becomes the standard method for compliance. Critics argue that many older coal plants will simply retire, but utilities and regulators increasingly view CCS as a practical alternative for maintaining essential system capacity and resilience.

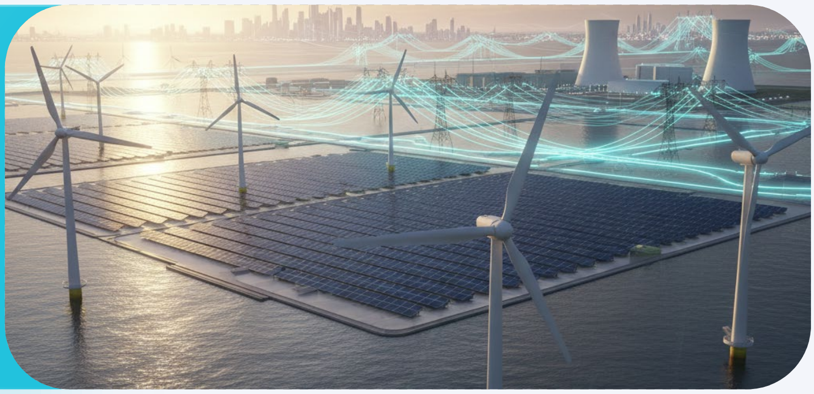
On the economic front, the Inflation Reduction Act (IRA) and other legislative measures have increased support for CCS deployment. The U.S. Department of Energy (DOE) Office of Fossil Energy and Carbon Management (FECM) has allocated substantial funding to advance carbon capture technology through its Point Source Carbon Capture program. This multi-year effort covers everything from bench-scale R&D to large-scale test centers and preliminary engineering studies, aiming for capture efficiencies over 95 percent while reducing long-term costs. By late 2024, DOE announced over a billion dollars in funding opportunities and pilot projects, resulting in more than 270 publicly announced CCUS initiatives nationwide, with projected capital expenditures in the tens of billions.

Despite this progress, CCS deployment remains controversial. Environmental justice advocates warn that investing in CCS could extend reliance on fossil-fuel generation, delaying the transition to fully renewable systems. Others argue that CCS provides a credible way to maintain essential baseload power without high-emission generation. In so-called "hard-to-abate" scenarios, such as industrial operations or grid balancing, CCS is often the only viable option for meaningful decarbonization at scale.

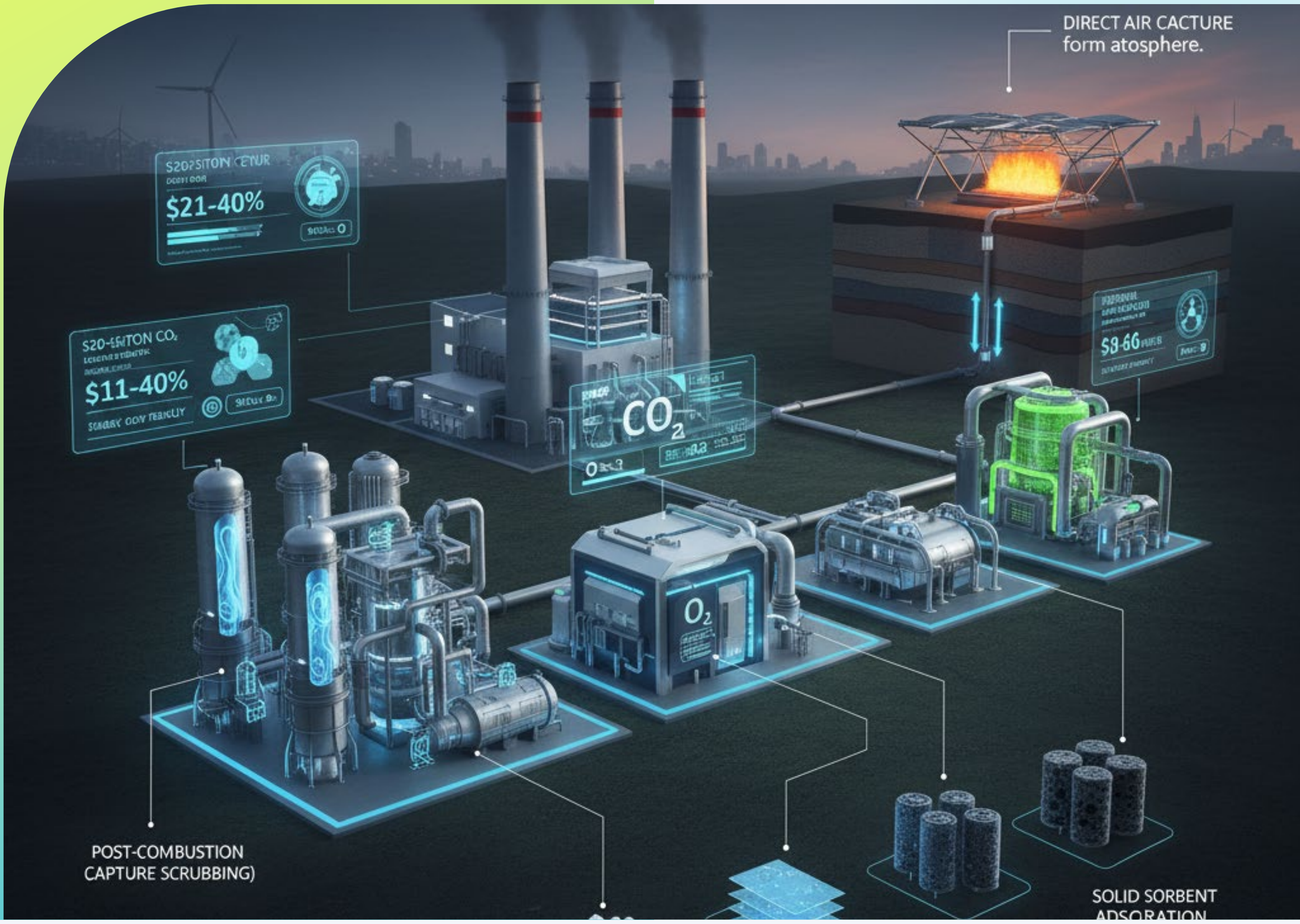
Beyond regulatory mandates and climate modeling scenarios aligned with the Paris Agreement, CCS also plays a key role in maintaining grid reliability as the share of intermittent renewables increases. Deep decarbonization pathways created by independent research institutions project an eightfold rise in capture capacity by 2030. The DOE and related national labs have expressed their commitment to supporting this expansion through hubs that combine capture facilities, transport pipelines, and storage infrastructure.

Considering the high emissions from the U.S. power sector, federal policy efforts, and the growing use of carbon capture technology, CCS and CCUS are essential components of the national decarbonization strategy. They offer a technical solution to reduce CO_2 emissions from existing infrastructure while maintaining grid stability. Without these tools, achieving U.S. climate goals by mid-century will be difficult, if not impossible.

U.S. power plants remain major CO_2 emitters, and even with growth in renewables, large-scale Carbon Capture and Storage (CCS/CCUS) is essential to meet 2035 decarbonization targets while maintaining grid stability.



Federal policies, regulations, and funding (IRA, DOE programs) are accelerating CCS adoption, making it a key—though debated—tool for reducing emissions from existing fossil-fuel infrastructure.



The Toolbox

Capture Technologies and How They Work

Carbon capture technology plays a key role in the CCS and CCUS landscape in the United States, especially in fossil-fueled power generation. Currently, capture systems are employed in various configurations—post-combustion, pre-combustion, oxy-fuel combustion, and emerging techniques like calcium looping, membrane separation, sorbent adsorption, and direct air capture. Each method offers different advantages, levels of technological development, and cost profiles that influence whether it is suitable for retrofits or new installations at coal and gas power plants.

Post-combustion capture is the most advanced method for retrofitting traditional pulverized coal and natural gas combined-cycle (NGCC) plants. In this process, CO_2 is removed from the flue gas exhaust using chemical solvents, most often aqueous amine-based scrubbers. The flue gas passes through an absorber where CO_2 binds with the solvent; then, heating in a stripper releases purified CO_2, which is subsequently compressed for transportation or storage, while the solvent is recycled. This method is well understood and mostly ready for commercial deployment today, with ongoing pilot programs testing new amine solvents and heat-integration improvements to reduce energy consumption and costs.

DOE-supported pilot projects have expanded the scale and efficiency of post-combustion systems. One example is a 10 MW_e demonstration at a coal-fired plant in Springfield, Illinois, using a solvent developed through industry collaboration to enhance heat recovery and reduce steam requirements. Additional testing at a Wyoming facility employs membrane-based separation, further demonstrating the potential for lowered parasitic loads and streamlined system design.

Precombustion capture takes place within integrated gasification combined cycle (IGCC) systems, where coal or natural gas is partially oxidized to produce syngas—mainly carbon monoxide and hydrogen. A water–gas shift reaction then converts CO into CO_2 and additional hydrogen. The CO_2 is subsequently separated—often using adsorption or membrane techniques—before the hydrogen stream is burned in a turbine. Although fewer IGCC plants currently operate in the U.S., DOE research emphasizes achieving high capture efficiencies and lower costs, rather than aiming for a specific dollar-per-ton figure. This technology is less common than post-combustion but may be suitable for new facilities that require high-purity capture from cleaner feeds.

Oxy-fuel combustion is another method being developed, where fuel is burned in a mixture of oxygen and recycled CO_2 or water vapor instead of ambient air. This process produces a flue stream mainly composed of CO_2 and water, making capture easier and reducing the need for extensive separation infrastructure. However, it requires oxygen production and modified combustion systems, which add complexity. Oxy-fuel remains in the demonstration or early pilot stage in the U.S. power sector and has not yet been adopted on a large commercial scale.

Calcium looping is an innovative second-generation capture technique that involves cyclic carbonation and calcination of limestone ($CaCO_3$/CaO) in fluidized-bed reactors. In the carbonator, the sorbent reacts with CO_2 to produce $CaCO_3$; in the calciner, heat releases CO_2 and regenerates CaO. This thermal integration lowers operational costs and energy penalties compared to amine scrubbing. The cost per ton of CO_2 captured is estimated at $24, versus $35–96 for amines. Although calcium looping is still experimental and not yet implemented in commercial power plants, it shows promise as a scalable, low-cost capture method when co-located with cement plants or fluidized bed combustion.

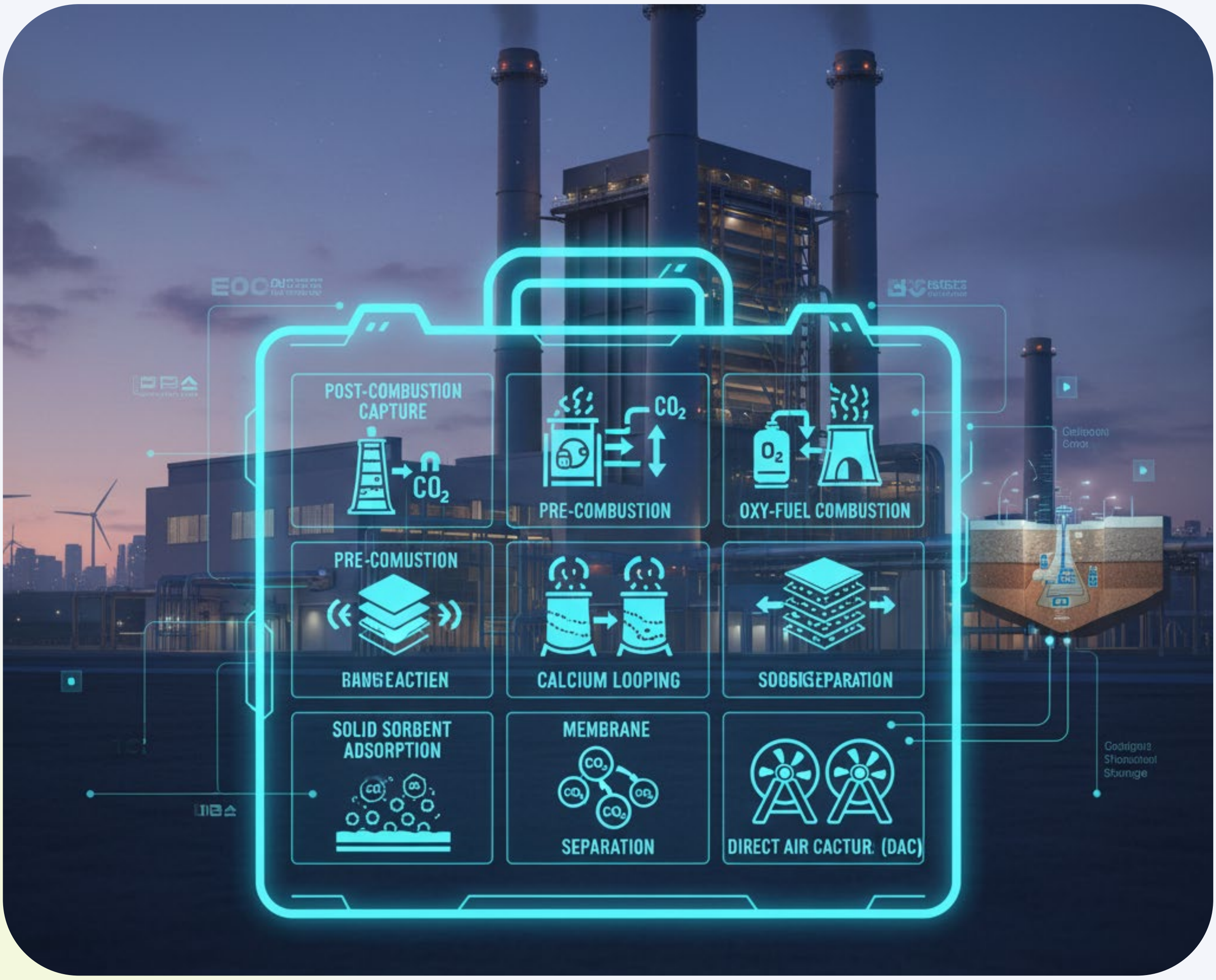
Solid sorbent systems and membrane technologies are rapidly advancing through DOE-supported test centers. Solid sorbents rely on physical adsorption to capture CO_2 at moderate temperatures with selective binding, then release the gas using vacuum or heat. These systems can reduce solvent degradation and material costs, but moisture and flue gas contaminants threaten their selectivity and durability. Membrane modules in development aim to separate CO_2 directly from flue streams with fewer moving parts and lower energy consumption, though scalability and long-term reliability remain concerns.

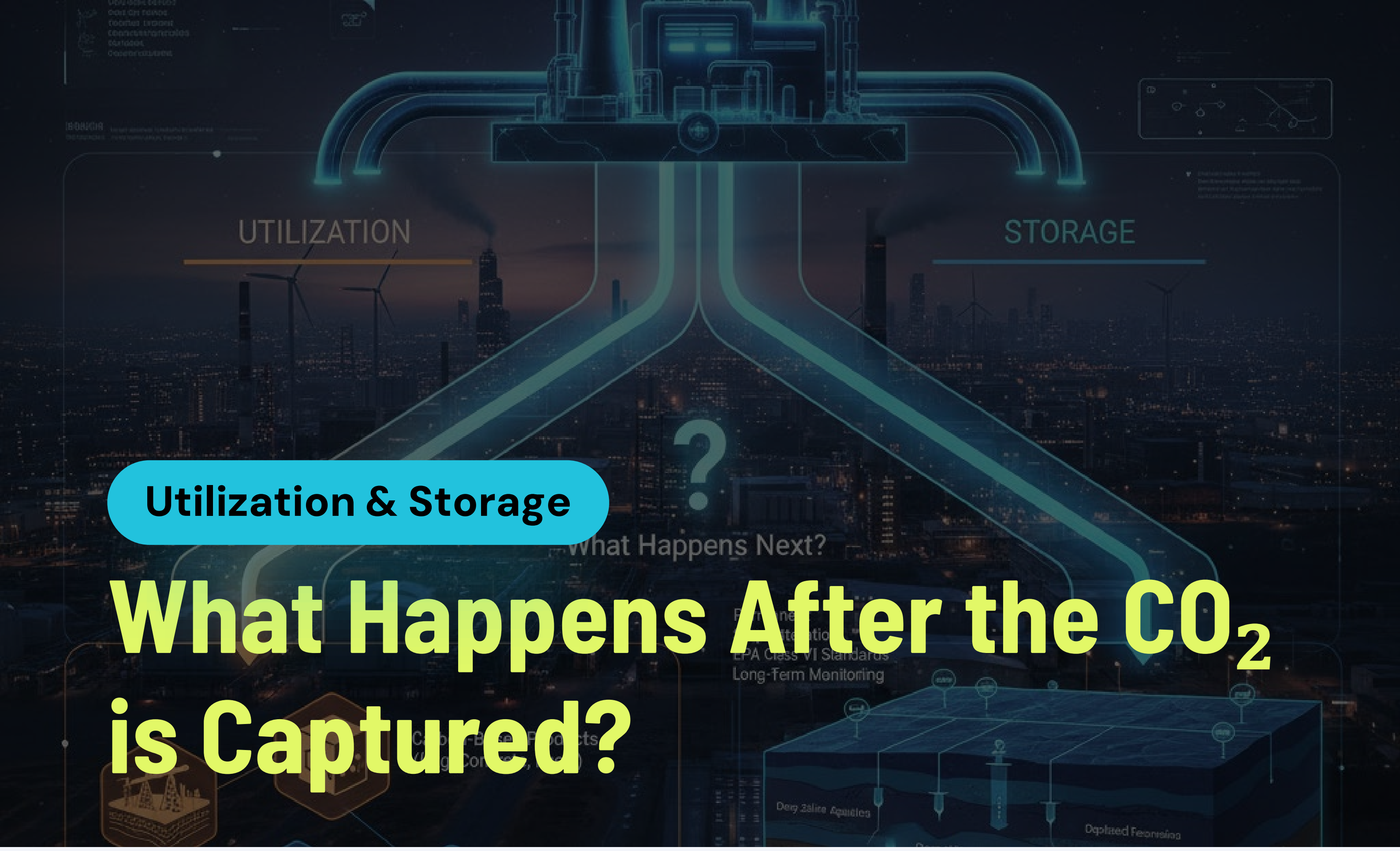
Direct air capture (DAC) differs technically from point-source methods. It removes CO_2 directly from the surrounding air using liquid or solid sorbents. Although DAC is not typically used on power plant stacks, it remains relevant to CCUS discussions, especially for offsetting remaining emissions. Federal support for DAC includes the Department of Energy's Carbon Negative Shot initiative, which aims to cut removal costs to below $100 per ton. DAC systems are categorized into solvent-based and sorbent-based types, each with distinct regeneration needs and energy requirements.

Regardless of the method, capture technology adds an energy penalty to host power plants. In coal-fired systems, the energy penalty results in about 14 to 40 percent more fuel consumption to produce the same amount of power. Natural gas facilities usually face an 11 to 22 percent penalty. This includes the energy needed for solvent regeneration, CO_2 compression, and transportation. Capture also increases water usage—coal plants with CCS may require up to 50 percent more water.

DOE and national laboratory-backed research, including multi-phase projects funded through the Point Source Carbon Capture Program and the Carbon Capture Demonstration Projects initiative, has led to significant improvements in capture system performance and scale. These efforts support front-end engineering and design, large pilot demonstrations, and integration testing in real-world settings to narrow the gap between laboratory results and site deployment.

In summary, post-combustion capture remains the most widely used method for U.S. power plant retrofits, while pre-combustion and oxy-fuel offer potential for high-efficiency new builds. Emerging techniques like calcium looping, sorbents, membranes, and DAC show promise for lowering costs and energy use. Together, these technologies form a diverse capture toolbox capable of adapting to different fuel types, plant designs, and emissions goals—the ongoing development of this toolbox positions CCS and CCUS as viable options for U.S. power sector decarbonization.





Utilization & Storage

What Happens After the CO_2 is Captured?

After CO_2 is captured at a power generation or industrial site, decisions must be made about how to manage it. In Carbon Capture Utilization and Storage (CCUS) frameworks, the captured gas can either be used in revenue-generating processes or injected into geological formations for permanent storage. Understanding this "U and S" phase is crucial for evaluating the climate benefits and scalability of carbon capture systems within U.S. energy infrastructure.

Utilization, mainly through Enhanced Oil Recovery (EOR), is currently the primary use for captured CO_2 in the United States. In EOR operations, CO_2 is injected into partially depleted oil reservoirs to increase pressure and mobilize remaining oil. The injected CO_2 becomes part of the oil recovery process, with many projects recycling the gas multiple times. While EOR allows for monetizing CO_2 and helps offset capital costs, critics argue it can reduce overall climate benefits: even as oil production increases, the full lifecycle emissions from the produced oil must be considered. Still, EOR remains a key part of many large-scale U.S. CCS projects connected to fossil fuel power generation, especially in Texas and other Gulf Coast regions.

Dedicated geological storage in deep saline aquifers or depleted oil and gas reservoirs is the most climate-friendly option within CCUS. Saline aquifers are common across the U.S., often lying more than one kilometer deep, and can safely hold supercritical CO_2 beneath sealing caprock formations. Storage in these formations does not produce hydrocarbons. Instead, captured CO_2 remains permanently trapped, gradually dissolving into formation fluids and minerals over time. Storage-only deployment requires fewer purity constraints than EOR applications and can therefore be more economically viable in some cases.

One of the most notable U.S. saline storage demonstrations is the Archer Daniels Midland (ADM) project near Decatur, Illinois. In this pioneering effort, CO_2 produced from corn-to-ethanol fermentation—achieving purity levels above ninety-nine percent—was compressed, dehydrated, and injected deep into the Mt. Simon Sandstone at over 7,000 feet deep. The project began continuous injection in 2011, and by 2020, had sequestered more than 2.7 million metric tons. Over its lifetime, ADM estimated that more than 4.5 million metric tons of CO_2 had been safely stored. The project features an integrated monitoring system, including deep observation wells and real-time pressure and temperature tracking, meeting Class VI U.S. EPA permitting standards. Its success increased confidence in saline formation storage and set a precedent for future industrial CCUS applications.

Although the early operational success of the Decatur project was notable, it also highlighted the risks related to subsurface CO_2 management. In 2024, ADM detected brine movement between geological formations about 5,000 feet deep and stopped injection until further testing could be performed. The Environmental Protection Agency later found that the company had violated parts of its Class VI permit by not following its emergency response plan and failing to monitor a deep well properly. ADM sealed the affected monitoring well and confirmed there was no threat to public health or local aquifers like the Mahomet Aquifer. However, the incident raised broader issues regarding site integrity, regulatory oversight, and community trust. Industry advocates responded by pointing out the system's ability to detect anomalies as proof of effective oversight, while critics stressed the need for stronger community engagement and risk mitigation procedures.

Geological storage operations in saline aquifers require robust subsurface engineering and regulatory frameworks. Research on optimization emphasizes proper well control strategies, managing injection pressure, reservoir characterization, and long-term monitoring to prevent leakage or unintended migration. Sealing formations, fault mapping, and real-time pressure monitoring help ensure containment over many years. Partnerships among universities, geological surveys, and agencies like the EPA are essential in developing site-specific safety plans that address environmental risks.

Beyond EOR and saline aquifers, other utilization options are emerging. Captured CO_2 is increasingly used as a raw material for making synthetic fuels, carbonated building products, and polymers. Mineralization processes, both in situ and ex situ, convert CO_2 into stable carbonate minerals when reacted with industrial waste or reactive rocks like basalt. These options vary in maturity and scale but provide the potential for permanent use rather than storage. These pathways are beginning to receive federal support through research and pilot funding programs.

Overall, the use and storage part of the CCUS value chain shows both current commercial practices and future options. EOR remains the most common method because of existing oilfield infrastructure and financial incentives. Saline aquifer sequestration, as demonstrated by ADM's Decatur site, offers a way to store CO_2 for climate goals with little commercial by-products. New opportunities for use and mineralization techniques expand options for capturing and permanently storing carbon. Safe, permanent, and verifiable storage depends on continuous technical work, regulatory supervision, and transparent stakeholder involvement.

CO_2 pathways

Utilization (EOR) vs. geological storage (saline aquifers).

ADM Decatur

Proved large-scale storage but raised oversight concerns.

Outlook

EOR leads now, but saline storage and new uses are growing.

Incentivizing Carbon Capture

45Q and Beyond

The economic viability of carbon capture, utilization, and storage mainly relies on public policy and financial support. In the U.S., Section 45Q of the Internal Revenue Code functions as the primary federal incentive. Enacted in 2008 and significantly expanded by the Bipartisan Budget Act of 2018 and subsequent laws, 45Q provides a tax credit per metric ton for qualified CO_2 that is captured and either securely stored or used in approved applications. Taxpayers who install certified carbon capture equipment before January 1, 2033—and who meet the capture thresholds—can claim this credit for up to twelve years. For power plants, the annual capture must exceed 18,750 metric tons, and the system's design capture rate must be at least 75 percent. Industrial facilities and direct air capture systems have similar thresholds adapted to their size.

The credit rates vary depending on usage and timing. For CO_2 stored in secure geological formations, projects with equipment activated on or after February 9, 2018, can claim the inflation-adjusted amount—currently $17 per ton. CO_2 used in enhanced oil recovery or other certified utilization pathways qualifies for an adjusted rate—currently $12 per ton. Direct air capture facilities receive higher credit levels—$36 per ton—for CO_2 removed from the atmosphere. Compliance with prevailing wage and registered apprenticeship requirements can further multiply these amounts by up to five times, significantly increasing the incentive's economic value.

Pre-2018 credit rates apply only to equipment placed in service before February 9, 2018; newer projects must use the updated credit structures. The credit is transferable or eligible for direct payment, enabling project developers to monetize it even before generating taxable income from the project—an essential feature for capital-heavy CCS installations.

Thirty-day recapture periods apply: if the CO_2 leaks or isn't properly stored within three years, part of the claimed credit must be repaid. Secure geological storage must meet U.S. EPA Class VI well standards, including monitoring, reporting, and verification protocols. Demonstrated compliance, such as traceable lifecycle accounting and measurement at both the capture site and storage destination, is required for the claim to be valid. Ownership of eligible carbon capture equipment determines who can claim the credit, with precise allocation based on contractual agreements or physical control.

Beyond 45Q, the Department of Energy has created programs to support CCS deployment. The DOE's Carbon Storage Assurance Facility Enterprise (CarbonSAFE) initiative aims to promote the development of commercial-scale saline storage infrastructure. Selected projects under CarbonSAFE must support the development of storage sites capable of securely containing 50 million metric tons or more of CO_2. DOE has allocated over $500 million in recent rounds under the Bipartisan Infrastructure Law to fund 23 projects across multiple states. CarbonSAFE funding covers site screening, geologic characterization, modeling, permitting, and public engagement activities.

CarbonSAFE aims to reduce technical, regulatory, and financial risks by advancing storage projects from feasibility studies to injection-ready status. By supporting all phases, from early pre-feasibility to permitting, CarbonSAFE lowers barriers to large-scale saline sequestration. DOE technical resources, along with regulatory coordination and public-private partnerships, work to accelerate deployment timelines and build community trust.

Supporting these federal efforts are other grant and loan programs managed by various agencies. The Department of Energy's Loan Programs Office and Office of Fossil Energy provide grants, cost-share funding, and credit support for the early design and construction phases of CCS projects. Regional development banks and state programs offer additional support, especially in areas with state-level carbon pricing or low-carbon fuel standards. Public–private partnerships, such as carbon contracts for difference (CCfDs), also emerge, offering guaranteed price floors for captured CO_2 and thus reducing market uncertainty for developers.

States like California, Illinois, and Louisiana provide additional incentives through low-carbon fuel standards, carbon auctions, and grants for industrial decarbonization. Many of these incentives work alongside 45Q, enabling CCS developers to combine several revenue streams. However, permitting delays remain: EPA Class VI issuance is slow, and state permits for pipeline transport and seismic risk assessments can push project timelines back by years.

Together, 45Q and DOE-led programs like CarbonSAFE establish a strong incentive system to support the capture, transportation, and long-term storage or use of CO_2 in power generation. Although incentives are significant, projects still face high initial capital costs, lengthy permitting procedures, and financial risks that can limit private investment. Public policy remains crucial in bridging these gaps—especially through clear regulations, financial aid, and mechanisms to ensure the long-term stability of storage.

45Q Credit

Per-ton tax incentives ($12–$36) for captured CO_2, transferable, with strict rules and recapture provisions.

CarbonSAFE

DOE program funding large saline storage projects (50M+ tons) to cut risks and speed deployment.

Support & Hurdles

Extra grants, loans, and state incentives help, but high costs and slow permitting remain barriers.

Sticker Shockyes,

The Cost of Capturing Carbon

The biggest challenge to widely implementing carbon capture, utilization, and storage (CCUS) in U.S. power generation is the high upfront and ongoing costs. Retrofitting existing coal-fired or natural gas combined-cycle (NGCC) plants with CO_2 capture systems significantly raises the overnight capital cost per kilowatt. According to U.S. Energy Information Administration estimates, adding a capture system to a new coal plant can boost the cost from around $3,000 to $6,600 per kW. A new NGCC plant with 90 percent capture might see its capital cost nearly triple to between $2,700 and $2,850 per kW. This increase is caused by capture modules, additional compression equipment, and energy integration systems needed to support high-purity CO_2 extraction.

The levelized cost of electricity (LCOE) for power plants with CCS also increases significantly. For coal-fired plants, adding CCS can raise electricity costs by $7 to $12 per megawatt-hour compared to operations without capture. For NGCC facilities, avoided CO_2 costs are usually between roughly $60 and over $114 per ton, depending on plant design, capacity factor, and capture efficiency. Cost estimates for capturing CO_2 from coal power plants range from $20 to $132 per ton, while natural gas facilities might cost between $49 and $150 per ton. These differences reflect variations in flue gas CO_2 concentrations, technology maturity, heat integration strategies, and deployment scale.

Retrofit projects—especially first-of-a-kind installations—often face the highest cost per ton due to nonrecurring engineering and integration risks. DOE and national laboratories indicate that "nth-of-a-kind" CCS plants could reduce LCOE by about 10 percent compared to first projects, but only if standardized designs, modular fabrication, and economies of scale are achieved. Even so, these incremental savings are modest compared to the overall cost premium.

Energy penalties further raise costs and lower efficiency. Coal plants with CCS may require 14 to 40 percent more fuel to produce the same net power, while NGCC facilities typically face an 11 to 22 percent penalty. Most of this penalty results from solvent regeneration and CO_2 compression. The increased fuel consumption boosts operational costs and upstream emissions unless decarbonized fuels are used. CCS systems can also raise

plant water demand by up to 50 percent, increasing costs, especially in water-scarce areas.

Operational and maintenance costs are also higher. Solvent degradation, CO_2 processing wear, and increased pressure drop in capture modules drive up ongoing expenses. A 2011 DOE/NETL study of retrofitted facilities estimated that capture and compression capital costs run into hundreds of millions of dollars. When combined with maintenance, labor, and regulatory compliance costs, total annual expenses can exceed $160 million for CCS retrofit projects. In one case, state regulators concluded that carbon capture retrofit was economically infeasible as "best available control technology," rejecting it due to cost.

Financing risk remains a significant obstacle. High capital needs, long payback periods, and unpredictable revenue streams—even with tax credits—make CCS projects hard to finance. Uncertainty about future carbon prices or demand for carbon utilization adds extra market risk. Although the 45Q tax credit provides up to $85 per ton of CO_2, depending on the application, it might not fully cover high capture costs, especially when those costs go over $100 per ton. In these situations, combined incentives and additional subsidies may be necessary to meet investment thresholds.

Infrastructure additions, especially CO_2 transport pipelines and storage hubs, increase the complexity and expense. While pipeline transportation costs can range from $2 to $14 per ton, storage costs in onshore saline formations add another $10 or more per ton. These upgrades bring extra capital and operational demands, and projects often require building new pipelines or storage facilities, which can involve lengthy permitting processes, right-of-way acquisitions, and local resistance.

When comparing CCS to renewables, economic challenges are evident. Solar and wind costs continue to decrease, with installed capital costs usually below $1,500 per kW and LCOEs from $30 to $75 per MWh, often lower with storage inclusion. Conversely, adding CCS to fossil fuel plants can nearly double capital costs and significantly increase electricity prices. Therefore, CCS is frequently justified more for maintaining flexibility and reliability rather than as a cost-competitive generation option.

In conclusion, while CCS technologies hold promises for deep decarbonization and grid support, their high capital and operational costs remain significant barriers. Capture costs range from $50 to $150 per ton, energy penalties can lower net efficiency by up to 40 percent, and financing complexities add to the difficulty. Therefore, strong policy support and standardized deployment pathways are essential to reduce costs and make these technologies commercially viable.

Case Studies

Lessons from the Field

- **Petra Nova Carbon Capture Project**
  Texas
- **ADM Decatur Bioenergy CCS Project**
  Illinois

CASE STUDY

Petra Nova Carbon Capture Project – Texas

The Petra Nova facility at the W.A. Parish Generating Station near Houston was a milestone in U.S. carbon capture history, marking one of the first large-scale implementations of post-combustion CCS retrofit on a coal-fired power plant. Designed to capture approximately 1.4 million metric tons of CO_2 annually via the KM-CDR Process, the project combined compressed CO_2 transport with enhanced oil recovery (EOR) operations. Technologically, Petra Nova demonstrated that high capture efficiency—over 90 percent—could be achieved in real-world power plant settings using amine solvent chemistry, along with cogeneration strategies to reduce energy penalties.

Financially, Petra Nova showcased both the potential and the risks of linking carbon capture to commodity markets. The operational model depended on revenue from EOR, which initially generated enough cash flow to cover capital and operating costs. Federal support, including an estimated $190 million DOE investment, along with tax credits from the 45Q incentive, helped address early funding gaps. However, the project revealed how vulnerable CCS can be to external price changes; when oil prices dropped in 2020, its financial foundation collapsed. Operations were shut down, and throughput was well below expectations in later years.

The importance of Petra Nova extends beyond just engineering feasibility. Its legacy lies in the detailed operational and logistical data it generated: real-time stack monitoring, solvent degradation profiles, pipeline integrity methods, and heat integration techniques. This data has shaped later retrofit designs, plant control systems, and integration plans. Additionally, the project's challenges highlighted the need for diverse revenue streams, long-term offtake agreements, and resilience to market fluctuations—valuable lessons for developers, regulators, and financiers.

Socially and politically, Petra Nova demonstrated the challenge of aligning carbon capture projects within fossil fuel value chains. Its reliance on EOR sparked debates among climate advocates, who questioned whether monetizing captured CO_2 through oil production might hinder overall emissions reductions. Despite this, the facility opened up opportunities for dialogue between industry, regulators, and the public regarding the trade-offs between technical success and climate credibility. The project's eventual shutdown served as a warning: CCS initiatives must be based not only on technical reliability but also on economically sustainable, climate-compatible designs.

Petra Nova's engineering successes, along with its financial and public scrutiny, make it a key early test case. It highlighted the challenge of balancing capture scale, energy requirements, and revenue goals. It showed that initial improvements in capture efficiency and integration are only part of the story—long-term viability depends equally on economic structure, market factors, and social acceptance. The lessons learned from Petra Nova continue to influence the development of next-generation systems, especially those involving retrofit approaches and EOR-related applications.

CASE STUDY

ADM Decatur Bioenergy CCS Project – Illinois

The Archer Daniels Midland CO_2 capture project near Decatur, Illinois, marked the United States' first large-scale demonstration of bioenergy with carbon capture and storage (BECCS). Managed under the Illinois Basin Decatur Project and later the IL CCS initiative, it captures over one million metric tons of biogenic CO_2 each year—produced through corn ethanol fermentation—and safely stores it in the deep saline formation called the Mount Simon Sandstone. Over more than ten years of continuous injection, total storage has surpassed three to four million metric tons. This innovative BECCS project showed a pathway to net-negative emissions, a key concept for reaching mid-century climate goals.

Technically, the project delivered a stable, high-purity feedstock, making the capture process easier compared to flue gas from combustion sources. Equipment operated under strict Class VI permitting standards, featuring strong monitoring and verification systems. Deep observation wells monitored pressure and temperature, while geophysical surveys assessed plume movement. The facility's ability to detect brine movement in 2024, along with quick response protocols, demonstrated operational maturity and effective risk management within permitted storage frameworks.

Beyond individual metrics, ADM Decatur's broader importance lies in validating geological sequestration regardless of how it is used. It demonstrated that storing CO_2 in saline aquifers, along with thorough monitoring and subsurface modeling, can meet strict regulatory and climate standards. The facility showed that high-purity CO_2 streams help reduce capture energy costs and decrease pre-treatment steps, setting a technical benchmark for industrial point-source CCS.

The pause in injection during 2024, triggered by the detection of unexpected brine migration, highlights the project's strong commitment to safety and regulatory compliance. Emergency stop procedures, well plugging, and transparency with regulators and nearby communities demonstrated governance standards that build public trust. Resuming injection with improved protocols showed the ability for adaptive management in real-world situations.

ADM Decatur's significance extends to scalability and future policy development. By capturing biogenic emissions, the project demonstrated a feasible way to achieve negative emissions from domestic industrial processes. Its success has influenced federal storage initiatives—such as DOE's CarbonSAFE—by establishing geotechnical, regulatory, and public engagement frameworks for saline storage wells. Additionally, the project has driven workforce training programs, public–private research collaborations, and state-level permitting policies based on real-world experience.

Decatur offers a replicable model for deep storage projects emphasizing climate, technology, and regulation. Its proven success in reliable operations, subsurface safety, and community engagement makes it a standard for future saline-based CCS hubs. It demonstrates that projects aimed at permanent sequestration—beyond EOR use—are both technically achievable and politically practical when managed with care and oversight.

The Debate

CCS Versus Renewables

Competing or Complementary?

Carbon capture technology often lies at the heart of a detailed debate about strategic priorities in climate policy. One perspective views CCS as a distraction from rapidly deployable renewable energy sources, arguing that taxpayer funds used for capture systems could be better invested in advancing wind, solar, and battery storage. Supporters of this view emphasize that the levelized cost of electricity for new clean generation has dropped significantly, making traditional baseload plus CCS projects less financially competitive.

Opposing views see CCS not as a competitor to renewables but as a complementary resource crucial for maintaining grid reliability and supporting the decarbonization of existing assets. While renewables generate inexpensive, zero-carbon energy, they have limited dispatchability. Carbon capture enables natural gas and coal plants to operate in a decarbonized state, providing reliable capacity during periods of low renewable output or transmission constraints. Supporters argue that extending the lifespan of existing infrastructure equipped with CCS can help sustain system resilience as renewable capacity grows.

A persistent debate centers on the use of captured CO_2 in enhanced oil recovery. Opponents argue that linking CCS to oil production could weaken its climate benefits by encouraging more fossil fuel extraction. Supporters argue that monetizing captured CO_2 through EOR enhances economic viability, particularly for early-stage projects, and that even with increased oil production, there can still be a net reduction in emissions compared to uncontrolled generation. Ultimately, critics urge caution, questioning whether EOR-based revenue models support long-term emissions reduction and climate goals.

Social equity and environmental justice are also important issues in this debate. Communities near fossil fuel plants—often historically marginalized or economically disadvantaged—may oppose CCS projects because they worry these initiatives will extend fossil fuel operations or bring new risks from pipelines and injection wells. Supporters say that responsible CCS can offer local economic benefits, create jobs, and support infrastructure investments in clean energy. The level of acceptance for CCS mainly depends on clear risk communication, real community involvement, and fair sharing of benefits.

Long-term planning further differentiates viewpoints. Many net-zero emissions scenarios developed for U.S. policy planning assume that renewables alone cannot eliminate all emissions because of limitations in hard-to-abate sectors and industrial processes. Carbon capture, especially when combined with bioenergy or direct air capture, offers ways to produce negative emissions. In contrast, centrist or rapid-decarbonization strategies focused on clean-energy dominance aim to reduce dependence on CCS, instead scaling up demand response, electrification, and long-duration storage to fully replace dispatchable fossil fuel systems.

Policy frameworks keep evolving to address these tensions. Federal programs are increasingly supporting renewables alongside incentives for CCS and grid upgrades. States and regions are planning both to expand renewable generation and to develop CO_2 transport and storage infrastructure simultaneously. The aim is often to create integrated portfolios where CCS is viewed not as competing with clean energy, but as complementing it by meeting specific needs in grid stability and emissions reduction.

Ultimately, CCS and renewables are not mutually exclusive. Renewables provide increasingly affordable zero-carbon energy, while carbon capture offers a way to decarbonize existing fossil fuel infrastructure and manage emissions in sectors less suited to electrification. Whether they remain allies or competitors depends on how CCS projects are designed, how climate benefits are defined, and how public trust is built through transparent governance, strong regulation, and community engagement. Investment strategies that consider cost, climate integrity, technical performance, and social acceptance can effectively combine both approaches.

Scaling the Future

What's Needed for Widespread Adoption

Achieving meaningful national-scale deployment of carbon capture, utilization, and storage in the United States depends on coordinated progress across several areas—strategic policy development, infrastructure growth, regulatory streamlining, and community involvement. As CCUS transitions from isolated pilot projects to fully integrated systems, scaling up necessitates both increased volumes and enhanced coordination in capture, transport, and storage.

At the heart of scaling is the development of regional CO_2 storage and transport hubs. The U.S. Department of Energy's Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Initiative seeks to advance storage complexes capable of securely capturing at least 50 million metric tons of CO_2 over 30 years. To date, DOE has allocated over $518 million to 23 projects across 19 states, supporting feasibility studies, site characterization, subsurface modeling, and permitting. These efforts aim to reduce development risks and streamline commercial-scale saline sequestration by 2026 and beyond.

Complementing storage development, efforts to build CO_2 pipeline infrastructure are essential. Existing pipelines cover only about 5,200 miles—far less than required. Independent studies show that the U.S. will need more than 21,000 to 25,000 km of interstate CO_2 trunk lines and approximately 85,000 km of spur connections for capture and storage sites. This level of expansion demands capital investments ranging from $170 billion to $230 billion. Cost models developed by DOE's NETL—such as the CO_2 Transport Cost Model and SimCCS—are actively guiding siting, pipeline routing, and shared infrastructure strategies to lower per-ton transport costs and accelerate deployment.

Scaling capture capacity is equally vital. To realize ambitious carbon-neutral or net-zero goals, analysts estimate that the country needs to increase capture systems to several hundred million tonnes annually by 2035. Reaching this scale requires multiple projects feeding into hub-based storage complexes: shared pipeline infrastructure, standardized regulatory approval, and economies of scale in engineering procurement help lower costs.

Policy frameworks must evolve to promote scaling up. Besides 45Q tax credits and cost-share grants, federal priorities include addressing financing gaps for pipeline development and establishing common-carrier pipelines with regulated access. Instruments like carbon contracts for difference could provide price certainty over multi-decade periods, reducing market risk. The Clean Air Task Force and Carbon Capture Coalition emphasize the need for a policy approach that extends beyond project-specific subsidies and emphasizes strategic infrastructure planning.

Permitting reforms also play a crucial role. EPA Class VI permitting processes for injection wells remain slow and resource-constrained, leading to delays of several years for projects. Federal coordination with states, clear timelines, and simplified review procedures are vital to enable timely site mobilization. Agencies are increasingly encouraged to support eligible hubs as regional permit zones, allowing multiple capture sources to feed into a single storage site.

Expanding scale further requires attention to social license. New infrastructure—pipelines, wells, monitoring facilities—often intersects with communities concerned about safety, water protection, and long-term liability. Successful hub and pipeline projects involve early consultation, transparent risk assessment, and fair benefit-sharing plans. Incorporating community advisory boards, regular MVA disclosures, and joint education programs helps build trust and confidence in project oversight.

Infrastructure expansion efforts must prioritize environmental justice. Pipeline routes, hub locations, and injection zones should avoid disproportionately impacting disadvantaged communities. Shared-infrastructure design tools now incorporate demographics and rights-of-way considerations without significantly increasing project costs—ensuring that equity is integrated into expansion plans from the start, not added later.

From a workforce and innovation standpoint, scaling impacts job creation, sector growth, and technological progress. DOE-sponsored CarbonSAFE projects support regional training pipelines. Meanwhile, funding from the Infrastructure Investment and Jobs Act—already exceeding $12 billion for CCS and related efforts—supports workforce development, data sharing, and collaboration across multiple sectors.

In summary, deploying CCS widely across the U.S. power and industrial sectors calls for a comprehensive, system-wide approach. Regional storage hubs connected by shared pipeline infrastructure, supported by consistent policies, streamlined permitting, and responsible community engagement, form the core of this plan. With targeted federal funding, coordinated regulation, and fair implementation, the U.S. can shift from isolated pilot projects to a unified national carbon management system—building the foundation for climate-compatible power and industrial operations at scale.

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