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TOO INFREQUENTLY ASKED QUESTIONS ABOUT CARBON CAPTURE AND STORAGE

PRESENTED BY
NO FALSE SOLUTIONS PA COALITION
AND BETTER PATH COALITION

SEPTEMBER 2024

Karen Feridun, Lead Author

Members of the Pennsylvania General Assembly

Via Electronic Mail

09/16/2024

Dear Members,

We write to express our ongoing concern with the state's interest in Carbon Capture and Storage, as evidenced by the vote on SB831 in July. We were, nevertheless, buoyed by the number of legislators who opposed the bill. It was heartening to hear some of the arguments we made in our position statements repeated during the floor debate. Now we urge you to pause before taking any further action on the implementation of Carbon Capture and Storage in Pennsylvania.

Our position statements laid out a case against Carbon Capture and Storage that emphasized how much research has yet to be done before we know about issues like site selection, the movement of CO2 plumes, a site's capacity, and even the definition of the term "permanent".

Much is already known, however, so we have written a brief we have titled *Too Infrequently Asked Questions About Carbon Capture and Storage*. We believe that the answers to the following questions recommend a pause, at minimum, on capturing and geologically sequestering carbon dioxide in Pennsylvania.

How much CO2 is emitted annually?

How much of that CO2 can CCS address?

Are CCS operations working at capacity?

What happens to the captured carbon?

Where does the captured carbon go?

What can EOR teach us about CCS?

What are the economics of capturing CO2?

Can stored CO2 leak?

What are the potential risks for leakage in Pennsylvania?

Is CCS worth the time and investment?

Our brief could have been much longer. Carbon Capture and Storage is a complicated topic.

We stand to lose so much when we are put in a position where we are subsidizing and taking on liability for a technology that strips us of our subsurface property rights, exposes us to dangerous infrastructure buildout, and ultimately fails to reduce emissions. Passing legislation does not

compel you to act on it. A matter as consequential as opening the Commonwealth to Carbon Capture and Storage requires careful and honest assessment of the issues we raise in our brief.

Respectfully,

Karen Feridun, Co-founder, Better Path Coalition

Dr. Karen Elias, Co-founder, No False Solutions PA

Rebecca Roter, Chairperson, Breathe Easy Susquehanna County

Jill Schneider, Ph.D., Chapter Chair, Climate Reality Chapter of the Lehigh Valley, PA

Sandy Field, PhD, Chair, Climate Reality Project: Susquehanna Valley PA Chapter and Save our Susquehanna

Barbara W. Brandom, MD, Concerned Health Professionals of Pennsylvania

Tracy Carluccio, Deputy Director Delaware Riverkeeper Network

Glenny Marcille-Kerslake, Pennsylvania Organizer, Food & Water Watch

Michael Sauers, Writer/Editor, Greenfire Coalition Writers' Forum

Tamela Trussell, Founder of Move Past Plastic (MPP)

Jay Notartomaso, Founder, NEPA Green Coalition

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cc: Governor Josh Shapiro

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Secretary Nancy Walker

Senator Gene Yaw

Executive Director Tim Schaeffer

Senator Carolyn Comitta

Executive Director Stephen Smith

Representative Greg Vitali

Chairman Stephen DeFrank

Representative Martin Causer

Too Infrequently Asked Questions About Carbon Capture and Storage

How much CO2 is emitted annually?

CO2 emissions continue to increase globally. In 2023, according to the International Energy Agency (IEA), global energy-related CO2 emissions set a record of 37.5 billion tonnes, representing a 1.1% increase (410 million tonnes) over 2022's record-setting total.ⁱ

How much of that CO2 can CCS address?

The Global CCS Institute estimated that the total annual capacity of CCS facilities in early or advanced development, under construction, and in operation in 2023 would be 361 million tonnes, or 0.7% of emissions.ⁱⁱ

The IEA estimates that the current rate of CCS development puts us on track to achieve just 40% of the annual 1GT (1000 million) of captured CO2 by 2050 in the Net Zero Emissions plan.

Currently, the total installed capacity of CCS is 49.7 million tonnes of CO2 per year, or around .1%, of global CO2 emissions, according to analysis from Oil Change International.ⁱⁱⁱ (CCS does not address other GHG emissions.)

To put it in context, the PA Department of Environmental Protection's GHG Inventory says Pennsylvania alone is responsible for roughly 1% of global GHG emissions^{iv}, 80.8% of which are CO2 emissions.^v

To further put it in context, the total capacity of all planned and operational CCS in 2023 is 361 million tonnes, 49 million tonnes less than the 410 million tonne increase in global CO2 emissions from 2022 to 2023.

The IPCC assessed the feasibility of more rapidly scaling up CCS in the fossil fuel sector. "The IPCC indicated that there are serious feasibility concerns over the large-scale deployment of CCS in the fossil fuel sector and that we ought to limit our expectations. Despite this, many emissions reduction models still design scenarios with fossil fuel CCS playing a much larger role (up to 10GtCO2/year by 2050) to compensate for slower declines in fossil fuel production and consumption. But achieving these levels of carbon storage would imply building the equivalent of the [world's biggest current carbon capture facility](#)—capturing about 7MtCO2/year—every week until 2050."^{vi}

The figure above from Oil Change International refers to installed capacity. Are CCS operations working at capacity?

A widely held critique of CCS is that it has overpromised and underdelivered.

As of 2021, 43% of all announced CCUS projects and 78% of the large-scale pilot and demonstration projects had been canceled or put on hold.^{vii}

One of the canceled projects, Golden Spread Electric Cooperative Inc.'s Mustang Station was the subject of a DOE-funded FEED study.^{viii} The study concluded that CCS was “not feasible because of the limited availability of water and the high number of renewable resources that are dispatched by the Southwest Power Pool in the geographic area where Mustang Station’s gas turbines are located.”^{ix}

A 2023 review by DeSmog of 12 CCS projects found that the projects fell short of targets, resulting in net increases in emissions.^x

The Environmental Working Group cites the example of the Petra Nova CCS operation in Texas that promised to reduce carbon emissions by 90%, but never achieved more than a 33% reduction in emissions from the 240 MW portion of the plant where capture was occurring^{xi} which translates to a 7% reduction plantwide during the three years it was in operation.^{xii}

Archer Daniels Midland’s ethanol plant set a goal of capturing 2,000 to 3,000 tons of CO₂ per day aided by \$281 million in government subsidies (not including tax breaks), but underdelivered^{xiii} by half to two thirds by capturing an average of 1,345 tons per day between 2017 and 2022. “EPA records also show that a monitoring well at the ADM facility leaked 307 tons of CO₂ in 2022, amounting to 0.07% (or 307 tons) of the carbon stored that year,” according to the Environmental Integrity Project’s Oil and Gas Watch.^{xiv}

An EPA violation notice that leaves the public with more questions than answers cites Archer Daniels Midland with allowing liquid CO₂ to migrate from its approved storage site. The violation issued in August for the migration that was discovered in June was not disclosed to the public until Politico reported it on September 12.^{xv} A company spokesperson told EE News that the amount of fluid that migrated totaled 8,000 metric tons.^{xvi}

What happens to the captured carbon?

Currently, the vast majority of captured carbon is not stored, but is used for Enhanced Oil Recovery (EOR), the process of injecting CO₂ into depleted wells to eke out remaining oil.

The Global CCS Institute (GCI) says approximately 68 million tonnes of CO₂ are transported each year through about 50 pipelines that total 6,500 km in length, mostly for EOR. GCI estimates that the current system would have to grow to 100 times its current size over the next 30 – 40 years to keep up with CCS deployment.^{xvii}

Princeton University published a Net Zero Report that used modeling to determine that it would take 68,972 miles of new pipeline in the U.S. by 2050 to move enough CO₂ to meet net zero goals. The modelers estimated that the system would cost \$135 billion dollars.^{xviii}

However, a JP Morgan analyst questions Princeton’s modeling. “The Princeton CCS buildout, just to sequester an amount equal to 15% of current US GHG emissions, would require infrastructure whose throughput volume would be higher than the volume of oil flowing through US distribution

and refining pipelines, a system which has taken over 100 years to build,” says Michael Cembalest in JP Morgan’s 2021 Annual Energy Paper.^{xix}

A CO2 pipeline disaster after heavy rains caused a landslide in Satartia, Mississippi in 2020 has raised safety concerns with the proposed buildout. Investigative journalist, Dan Zegart, described people who staggered like zombies and cars that stopped running because CO2 is an asphyxiant that displaces ambient oxygen. Forty-nine people were hospitalized. Fortunately, none of them died, but several are dealing with permanent disabilities due to their exposure.^{xx}

Accufacts explained in a 2022 report commissioned by the Pipeline Safety Trust, “Running ductile fractures are unusual and particularly dangerous fractures that can ‘unzip’ a CO2 transmission pipeline for extended distances exposing great lengths of the buried pipeline. These extreme rupture forces throw tons of pipe, pipe shrapnel, and ground covering, generating large craters along the failed pipeline. It is well known that CO2 pipelines operating in dense phase, either supercritical or as a liquid, are particularly susceptible to such running ductile fractures.”^{xxi}

Where does the captured carbon go?

The Institute for Energy Economics and Financial Analysis estimates that 80 – 90% of captured carbon goes into depleted wells for Enhanced Oil Recovery (EOR).^{xxii}

EOR has been used most often in the Permian Basin in western Texas and eastern New Mexico. It has also been used less frequently in Kansas, Mississippi, Wyoming, Oklahoma, Colorado, Utah, Montana, Alaska, and Pennsylvania.^{xxiii}

The Congressional Budget Office reported in December 2023 that only 15 CCS facilities are currently in operation in the U.S. and that, of them, only two of them do not use captured carbon for EOR. The Illinois Industrial plant on the table below is referred to elsewhere in this report as the Archer Daniels Midland plant.^{xxiv}

Name of Facility	Date CCS Operations Began	Location	Type of Production	CO ₂ Used for Enhanced Oil Recovery?	CO ₂ Capture Capacity (Millions of metric tons per year)
Terrell	1972	Texas	Natural Gas Processing	Yes	0.5
Enid Fertilizer	1982	Oklahoma	Ammonia (Fertilizer)	Yes	0.2
Shute Creek	1986	Wyoming	Natural Gas Processing	Yes	7.0
Great Plains	2000	North Dakota	Hydrogen and Ammonia (Fertilizer) ^a	Yes	3.0
Core Energy	2003	Michigan	Natural Gas Processing	Yes	0.4
Arkalon	2009	Kansas	Ethanol	Yes	0.5
Century Plant	2010	Texas	Natural Gas Processing	Yes	5.0
Bonanza BioEnergy	2012	Kansas	Ethanol	Yes	0.1
Air Products	2013	Texas	Hydrogen	Yes	0.9
Coffeyville	2013	Kansas	Hydrogen and Ammonia (Fertilizer) ^a	Yes	0.9
Lost Cabin	2013	Wyoming	Natural Gas Processing	Yes	0.9
PCS Nitrogen	2013	Louisiana	Ammonia (Fertilizer)	Yes	0.3
Petra Nova	2017 ^b	Texas	Electric Power	Yes	1.4
Illinois Industrial	2017	Illinois	Ethanol	No	1.0
Red Trail Energy	2022	North Dakota	Ethanol	No	0.2

Although the facilities are listed as CCS operations, little to no CO₂ storage is done. Companies with CCS operations follow a “Sell or Vent” model. Because of the volatility of the oil market, the time to sell CO₂ for EOR is when prices, and demand, are high. The rest of the time, the CO₂ is vented into the atmosphere.^{xxv}

On its best day, EOR is still about extracting more oil.

It was not until 2010 that the EPA established a class of Underground Injection Control (UIC) well for “permanent” disposal of CO₂ called a Class VI well.

The CO₂ is injected a half-mile or more below the surface where it is purportedly stored in the pore space of rocks located below a cap rock, an impenetrable rock that will not allow the CO₂ to escape.

Class VI wells are still relatively rare. EPA has issued four permits for Class VI wells, two for the Archer Daniels Midland plant in Illinois and two for Wabash Carbon Services in Indiana. Three states have been granted primacy for Class VI injection wells - North Dakota, Wyoming, and Louisiana. North Dakota has issued 8 permits, Wyoming has issued 3, and Louisiana has not issued any to date.

What can EOR teach us about CCS?

Very little.

Stephen Rassenfoss explains in the *Journal of Petroleum Engineering*, “While a lot has been learned from EOR (enhanced oil recovery), there may well be significant differences between cycling just enough gas through a reservoir to increase production and injecting as much gas as possible for permanent storage, often in unfamiliar sorts of formations.”^{xxvi}

He was writing about plume modeling, or what happens to the CO₂ plume when it exits the injection well.

Bruce Craig and Adam Rowe wrote in a guest editorial for the same journal that EOR does not tell us much about CCS injection well metallurgy either. “The reason there is little or no merit to applying this experience to CO₂ CCS wells is the lack of data specific to the long-term corrosion resistance of casing that remains in the EOR wells. Rather, the industry generally simply plugs these wells with cement, and in the majority of cases without examining the casing before abandoning. Furthermore, industry rarely returns to inspect them after years of abandonment,” say Craig and Rowe.^{xxvii} They lay out some of additional differences in the table below.

Parameter	EOR	CCS	Comments
CO ₂ Composition	CO ₂ , H ₂ S, CH ₄ , N ₂	CO ₂ , H ₂ S, O ₂ , H ₂ , SO _x , NO _x , etc. (Craig et al.)	Impurities have a significant effect on corrosion, especially carbon steels.
Reservoir Type	Depleted oil formation	Saline formation	The chloride content of the water is often much higher in saline reservoirs.
Depths, ft	Typically, 3,000 to 7,000 (Meyer and NETL)	5,000 to 10,000	
Temperature Range, °F	<250 (NETL) <120 optimum (El-hoshoudy and Desouky)	125 to 260	Temperature is more important than pressure and depth from a materials standpoint.
Pressure Range, psi	>1,200 to 1,500 (NETL) >3,000 optimum (El-hoshoudy and Desouky)	2,000 to 6,000	
EPA Permitting	Class II	Class VI	

Table 1—Side-by-side comparison of differences between EOR and CCS wells.

Larry Lake, who spent his career in EOR, agrees with the difference Craig and Rowe cites regarding the composition of the gas. The CO₂ used in EOR has few impurities because of its source, whereas CO₂ from industrial exhaust is much dirtier.^{xxviii}

However, Lake believes the most obvious difference is in the economics of EOR vs. CCS.^{xxix} It is also where we can take our best lesson from EOR. Selling CO₂ is a way to offset the high cost of carbon capture.

What are the economics of capturing CO₂?

According to the Congressional Budget Office, “The main reason CCS is used to such a limited extent is that the cost to implement CCS technology exceeds its value in most potential settings. Estimates of the cost to capture CO₂ come mainly from engineering and economic modeling and can vary widely depending on the assumptions made in that modeling. An indicative range of estimates is from about \$15 to \$120 per metric ton of CO₂ captured, with additional costs for transporting and storing the CO₂. Sectors at the lower end of that range provide fewer opportunities for capturing significant amounts of CO₂. Relatively large sources of CO₂ emissions, such as electric power generation and some industrial production, tend to have CO₂ capture costs toward the upper end of that range. Consequently, those sectors have had little economic reason to adopt CCS. The main financial incentives to use CCS are revenues from enhanced oil recovery and a federal tax credit for capturing and storing CO₂.”^{xxx}

The global EOR market size was \$48.5 billion in 2023. At the rate it is growing, it is projected to be \$97.2 billion by 2033.^{xxxi}

Carbon Capture and Storage is sometimes called a “publicly funded sewer system.”^{xxxii}

Permanently storing CO₂ means treating it as a waste, not a product. To incentivize storing CO₂ waste, the Inflation Reduction Act (IRA) increased the 45 Q tax credit created in 2008, although those who sell CO₂ for EOR can also benefit from the tax credit.

The IRA provides tax credits USD 85 per tonne of CO₂ permanently stored and USD 60 per tonne of CO₂ used for enhanced oil recovery (EOR) or other industrial uses of CO₂ under section 45Q of the IRS code. The law requires that emissions reductions must be clearly demonstrated in order to qualify for the tax credits, but how that is done is not at all clear.

Both the IRS and EPA are involved in reporting of emissions reductions, but the process is confusing and replete with opportunities for fraud. One of the more confounding problems is that parties taking the tax credit report it on their tax returns that are confidential and cannot be shared with, or verified by, anyone.

As the Biden administration and Congress started proposing increases to 45Q, Taxpayers for Common Sense charged that \$894 million of the \$1 billion taken in tax credits between 2010 and 2019 were based on insufficient data and fraudulent claims.^{xxxiii}

Can stored CO₂ leak?

Naomi Oreskes, probably best known as the co-author of *Merchants of Doubt*, wrote in an essay in *Scientific American* in March 2024 that she is among geologists who believe that long term CO₂ storage could be achieved, but that its success relies on identifying sites where CO₂ will remain sequestered. “But site characterization takes time that we don’t have,” she says. She points out that billions were spent over two decades to evaluate Yucca Mountain as a site for nuclear waste disposal before the proposal failed. Identifying sequestration sites is just as challenging.

“We all know the saying that what goes up must come down, but the opposite is largely true, too (at least if the materials involved are liquid or gas), because fluids migrate through the microscopic holes and fractures that are found in even the most solid of rocks,” she explains.^{xxxiv}

Equinor’s Sleipner and Snøhvit CCS projects in Norway have been cited as proof that CO₂ storage works. Extensive work was done on both projects to identify appropriate sites. Nevertheless, in less than three years, CO₂ had migrated up to just underneath the cap rock and where it quickly accumulated in volume on the Sleipner project. The Snøhvit project had to be suspended after only 18 months of operation due to rapidly increasing pressure in the storage location.^{xxxv} In 2023, Equinor said it was canceling plans to expand CCS operations because “it would have been both industrially and financially irresponsible.”^{xxxvi}

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories devotes a chapter to providing guidance on tracking emissions from CCS. The chapter looks at emissions from capture, transport, injection, and storage.^{xxxvii}

The table below identifies the potential pathways for stored CO₂ to leak.

TABLE 5.3
POTENTIAL EMISSION PATHWAYS FROM GEOLOGICAL RESERVOIRS

Type of emission	Potential emissions pathways/sources	Additional comments
Direct leakage pathways created by wells and mining	<ul style="list-style-type: none"> Operational or abandoned wells 	<ul style="list-style-type: none"> It is anticipated that every effort will be made to identify abandoned wells in and around the storage site. Inadequately constructed, sealed, and/or plugged wells may present the biggest potential risk for leakage. Techniques for remediating leaking wells have been developed and should be applied if necessary.
	<ul style="list-style-type: none"> Well blow-outs (uncontrolled emissions from injection wells) 	<ul style="list-style-type: none"> Possible source of high-flux leakage, usually over a short period of time. Blowouts are subject to remediation and likely to be rare as established drilling practice reduces risk.
	<ul style="list-style-type: none"> Future mining of CO₂ reservoir 	<ul style="list-style-type: none"> An issue for coal bed reservoirs
Natural leakage and migration pathways (that may lead to emissions over time)	<ul style="list-style-type: none"> Through the pore system in low permeability cap rocks if the capillary entry pressure is exceeded or the CO₂ is in solution 	<ul style="list-style-type: none"> Proper site characterization and selection and controlled injection pressure can reduce risk of leakage.
	<ul style="list-style-type: none"> If the cap rock is locally absent 	<ul style="list-style-type: none"> Proper site characterization and selection can reduce risk of leakage.
	<ul style="list-style-type: none"> Via a spill point if reservoir is overfilled 	<ul style="list-style-type: none"> Proper site characterization and selection, including an evaluation of the hydrogeology, can reduce risk of leakage.
	<ul style="list-style-type: none"> Through a degraded cap rock as a result of CO₂/water/rock reactions 	<ul style="list-style-type: none"> Proper site characterization and selection can reduce risk of leakage. Detailed assessment of cap rock and relevant geochemical factors will be useful.
	<ul style="list-style-type: none"> Via dissolution of CO₂ into pore fluid and subsequent transport out of the storage site by natural fluid flow 	<ul style="list-style-type: none"> Proper site characterization and selection, including an evaluation of the hydrogeology, can determine/reduce risk of leakage.
	<ul style="list-style-type: none"> Via natural or induced faults and/or fractures 	<ul style="list-style-type: none"> Possible source of high-flux leakage. Proper site characterization and selection and controlled injection pressure can reduce risk of leakage.
Other Fugitive Emissions at the Geological Storage Site	<ul style="list-style-type: none"> Fugitive methane emissions could result from the displacement of CH₄ by CO₂ at geological storage sites. This is particularly the case for ECBM, EOR, and depleted oil and gas reservoirs. 	Needs appropriate assessment.

What are the potential risks for leakage in Pennsylvania?

Pennsylvania's Department of Conservation and Natural Resources says it has been researching CCS for the past two decades, but the three reports it always cites were written 15 years ago shortly after the fracking boom began.

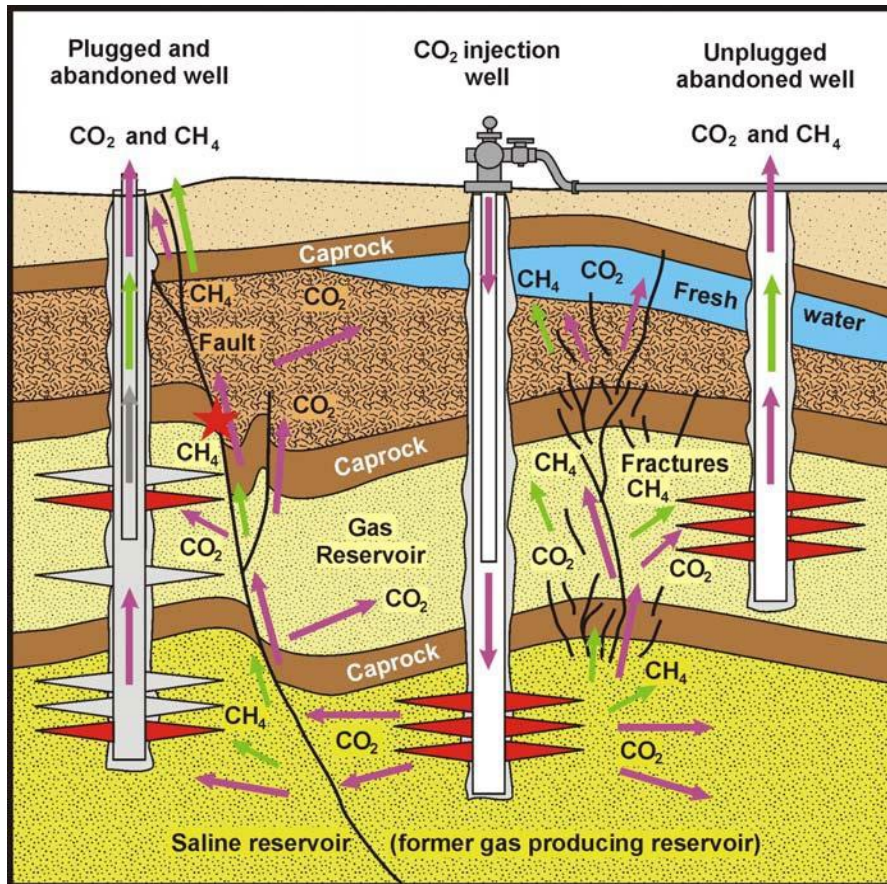
One of the 2009 DCNR reports stated, "The Marcellus Shale would likely be an appropriate cap rock, but continued exploration and potential development in this unit for natural gas production could potentially compromise the integrity of this formation as a viable cap rock in areas of natural gas production. Further evaluation of the structural geology of the Salina Group will be required to evaluate the potential for vertical migration of CO₂."^{xxxviii}

Regarding the Onondaga Limestone, the report says, "This hydraulic fracturing will likely compromise the suitability of the Marcellus shale as a cap rock in many areas, and may impact the underlying Onondaga Limestone as well. This potential impact should be evaluated further."

And the Oriskany? "It should be noted that the Marcellus Shale is the ultimate cap rock for the Oriskany Sandstone, although in some places other formations directly overlie the Oriskany Sandstone. The development of the Marcellus Shale creates difficulty with respect to its resulting containment of any CO₂ sequestered in the Oriskany. In terms of the deeper saline formations, wells installed into these units will penetrate through the Marcellus Shale. In addition to the Marcellus, Pennsylvania is home to an active oil and gas industry that during a typical year drills thousands of producing oil and gas wells. These wells penetrate the entire geologic section from the Upper Devonian through the Silurian. Each of the wells drilled to the saline units will penetrate these same formations. The crucial elements of containment include well integrity (increased casing and cement requirements) and cap rock integrity which results in isolation of these producing formations. The preferred approach would be to designate specific areas for CO₂ injection only, away from areas of active oil and gas operations," which, as *Global Energy Monitor* noted, "could prove extremely difficult at a time when gas is a tradable commodity, but carbon isn't."^{xxxix}

However, the IPCC guidance cautions that "inadequately constructed, sealed, and/or plugged wells may present the biggest potential risk for leakage."^{xl}

Another DCNR 2009 report similarly cautioned, "Injecting CO₂ into an area occupied by unplugged or improperly plugged wells invites leakage, especially if the injection reservoir formerly acted as an oil and/or natural-gas producing or gas-storage reservoir. In Pennsylvania's older oil-and-gas fields, many drill holes exist that can constitute a leakage pathway for reservoir gases, including injected CO₂. The safest course of action would be to avoid the oldest of these oil fields, such as those in the northwestern counties (especially Venango, Warren, and McKean), because those areas contain large numbers of oil wells drilled in the late 19th century for which no completion records currently remain."^{xli} (see figure below) Today, the estimated number of abandoned wells is at least three times higher than the 2009 estimate. Some current estimates are closer to six times higher. Many are undocumented and may never be found.



That Pennsylvania is considering carbon sequestration at all has not been explained. The Grand Jury report on fracking issued in 2020 states, regarding injection wells, “The fact that Pennsylvania’s geology is not conducive to these wells means they are not a viable local option to the fracking industry’s wastewater problem.”^{xlii} The Grand Jury was referring to Class II underground injection wells used for oil and gas waste, but there is no reason to think that Class VI wells are better suited to our geology.

Is CCS worth the time and investment?

“With the world suffering the impacts of a worsening climate crisis, continuing with business as usual is neither socially nor environmentally responsible,” said IEA Executive Director Fatih Birol. “Oil and gas producers around the world need to make profound decisions about their future place in the global energy sector. The industry needs to commit to genuinely helping the world meet its energy needs and climate goals – which means letting go of the illusion that implausibly large amounts of carbon capture are the solution.”^{xliii}

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- ⁱ <https://www.iea.org/reports/co2-emissions-in-2023/executive-summary>
- ⁱⁱ https://res.cloudinary.com/dbtfcnfij/images/v1699421934/CD7557_Global-Status-of-CCS-Report-Updated-08-11-23/CD7557_Global-Status-of-CCS-Report-Updated-08-11-23.pdf?_i=AA
- ⁱⁱⁱ <https://priceofoil.org/2023/11/30/ccs-data/#:~:text=An%20analysis%20by%20OCI%20of,facilities%20they%20are%20attached%20to>
- ^{iv} <https://gis.dep.pa.gov/ClimateChange/index.html>
- ^v https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/ClimateChange/FINAL_2023_GHG_Inventory_Report_12.13.23.pdf
- ^{vi} <https://www.iisd.org/articles/insight/unpacking-carbon-capture-storage-technology>
- ^{vii} <https://www.sciencedirect.com/science/article/abs/pii/S030142152100416X#:~:text=Another%20explanation%20is%20the%20high,an%20unsustainable%20cycle%20of%20innovation.>
- ^{viii} <https://www.energy.gov/oced/articles/doe-announces-selections-carbon-capture-front-end-engineering-design-studies>
- ^{ix} <https://www.electric.coop/epa-power-plant-rule-golden-spread-statement-of-harm>
- ^x <https://www.desmog.com/2023/09/25/fossil-fuel-companies-made-bold-promises-to-capture-carbon-heres-what-actually-happened/>
- ^{xi} <https://energyandpolicy.org/petra-nova/>
- ^{xii} <https://www.ewg.org/news-insights/news/confronting-myth-carbon-free-fossil-fuels-why-carbon-capture-not-climate>
- ^{xiii} <https://news.oilandgaswatch.org/post/in-illinois-a-massive-taxpayer-funded-carbon-capture-project-fails-to-capture-about-90-percent-of-plants-emissions>
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- ^{xvixvi} <https://www.eenews.net/articles/first-us-co2-injection-well-violates-permit-epa/>
- ^{xvii} https://www.globalccsinstitute.com/wp-content/uploads/2018/12/Global-CCS-Institute-Fact-Sheet_Transporting-CO2-1.pdf
- ^{xviii} <https://netzeroamerica.princeton.edu/img/nzap-pennsylvania-report.pdf>
- ^{xix} <https://am.jpmorgan.com/content/dam/jpm-am-aem/global/en/insights/eye-on-the-market/future-shock-amv.pdf>
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- ^{xxi} <https://pstrust.org/wp-content/uploads/2022/03/3-23-22-Final-Accufacts-CO2-Pipeline-Report2.pdf>
- ^{xxii} <https://ieefa.org/articles/carbon-capture-decarbonisation-pipe-dream>
- ^{xxiii} <https://www.energy.gov/fecm/enhanced-oil-recovery#:~:text=DOE's%20R%26D%20program%20is%20moving,Mexico%20into%20basins%20much%20c loser>
- ^{xxiv} <https://www.cbo.gov/publication/59832>
- ^{xxv} <https://ieefa.org/articles/shute-creek-worlds-largest-carbon-capture-facility-sells-co2-oil-production-vents-unsold#:~:text=%E2%80%9COil%20and%20gas%20companies%20with,licence%20to%20ramp%20up%20 production.%E2%80%9D>
- ^{xxvi} https://drive.google.com/file/d/1aYT_E0Ksyak8LtGmHtFrhdO6gHs0K1bl/view
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- ^{xxix} <https://jpt.spe.org/what-co2-eor-has-already-taught-us-about-upscaling-permanent-carbon-sequestration>

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