Too Good to Be True:

The Risks of Public Investment in Carbon Capture and Sequestration (CCS)

Western Organization of Resource Councils
Grassroots Leadership & Action

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About this Report

This report is a publication of the Western Organization of Resource Councils (WORC). This report was prepared by Colin Lauderdale and edited by Sara Kendall and Dan Cohn. All views and opinions expressed in this report are those of WORC and do not necessarily reflect the views of WORC's funders. Any errors are the responsibility of WORC.

About WORC

WORC is a regional network of grassroots community organizations that include 15,190 members and 39 local chapters. WORC's network includes: Dakota Resource Council (North Dakota); Dakota Rural Action (South Dakota); Idaho Organization of Resource Councils; Northern Plains Resource Council (Montana); Oregon Rural Action; Powder River Basin Resource Council (Wyoming); Western Colorado Congress and Western Native Voice (Montana). WORC's mission is to advance the vision of a democratic, sustainable, and just society through community action. WORC is committed to building sustainable environmental and economic communities that balance economic growth with the health of people and stewardship of their land, air, and water.

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EXECUTIVE SUMMARY

As the global effects of climate change become undeniable, both market actors and governments around the world are working to reduce greenhouse gas (GHG) emissions. State and federal politicians, the coal industry, and even some environmental organizations support Carbon Capture and Sequestration (CCS) technology as a strategy to continue to generate electricity with coal in a carbon-constrained future.

The industry's hope that coal can provide electricity while decreasing carbon emissions without drastically raising electricity costs and causing environmental damage is simply too good to be true. CCS technology faces both technological and economic obstacles that make public spending on CCS technology a poor investment of taxpayer dollars. From capture to transport to storage, CCS technology has proven itself to be expensive, inefficient, unreliable, and insecure, despite billions in public investment so far.

CCS projects have proven the technology's many drawbacks, including the following:

STORAGE

Storing carbon dioxide (CO_2) under pressure is a major safety concern. Several CO_2 storage demonstration projects have experienced catastrophic "blowouts" of compressed CO_2 via natural or man-made geologic fissures.[1] Carbon storage sinks that have not yet leaked or exploded have developed fissures or fractures in "cap rock" due to the high pressure of injected compressed CO_2.[2,3]

UTILIZATION

Enhanced Oil Recovery (EOR) is not a carbon sequestration technology. EOR is the most common method of CO_2 "utilization," in which captured waste CO_2 is pumped into oil reservoirs to stimulate production. Pumping CO_2 into oil fields does increase oil production, but it does not permanently capture or sequester CO_2 emissions.[4]

EFFICIENCY

CCS coal plants are fundamentally inefficient and drive up electricity costs. CCS equipment consumes a significant share of a plant's electricity, decreasing overall thermal efficiency by 10-12 percentage points, according to most studies. Efficiency can be expected to drop from a typical 38% to as low as 16%.[5] This dramatically increases a plant's use of coal without increasing its revenue from selling power, and makes its electrical output even more expensive.[6]

TRACK RECORD

Public investments in CCS projects have cost billions and have not paid off. There is only one operational coal-with-CCS facility (240 MW) in the United States, despite billions of taxpayer and ratepayer dollars spent on CCS demonstrations ($4.8 billion during the Obama Administration alone).[7] Even that one project, which was subsidized by hundreds of millions of public dollars, is expected to lose money for its owners.[8]

COST

Coal-fired power plants with CCS technology make use of coal, a nonrenewable resource that is already running out.[9] The cost of generating electricity by coal with CCS technology will only increase over time as coal becomes more scarce, while the cost of electricity from renewable energy is already lower than the price of electricity from coal plants using CCS and will continue to decline. Renewable energy solutions are cheaper, cleaner, and faster to deploy than CCS generation.[10] Even after decades of CCS research, relatively little private capital has been invested in CCS projects, whereas wind and solar energy will have access to trillions of dollars of financing over the next 20 years.[11]

If no other low-carbon, cost-competitive energy sources were available, public investment in CCS would be required to address rising greenhouse gas (GHG) concentrations. Fortunately, coal-fired power with CCS is not the only low-carbon energy option available – it is just the most expensive. Other technologies are much closer to accomplishing the goal of providing affordable electricity while reducing climate change-causing GHG emissions.[12]

Despite the technological and economic headwinds facing CCS, members of Congress and consecutive Presidents from both major political parties have pressed for increased federal spending in the sector. Public spending on CCS projects has taken the form of Department of Energy grants for demonstration projects that capture or store carbon dioxide, as well as tax credits awarded to companies who pump carbon underground for storage or enhanced oil recovery. Under the new Administration, coal companies, fossil fuel trade organizations, and some politicians are proposing dramatic increases in federal spending on CCS tax credits and demonstration projects, ignoring the harsh technological and economic realities of carbon capture and storage facilities.

Every dollar spent on CCS is a dollar spent on already outdated technology, and is a dollar not available for investment in cheaper, cleaner, and simpler energy solutions. Our political leaders should refrain from increasing spending to support the challenged CCS sector and should instead direct public dollars toward cheaper, cleaner, and more efficient renewable energy resources such as wind and solar generation, time-of-use pricing, and grid management technologies. Investing in these clean energy solutions will result in a market-based, low-carbon energy future with cheaper electric bills, cleaner air, and a reduced threat of catastrophic global climate change.

Credit: Michael Stravato/The New York Times/Redux.

Carbon capture equipment at the Petra Nova plant near Houston, Texas. Petra Nova is the only operating coal plant that captures carbon dioxide in the United States.

INTRODUCTION

Carbon dioxide (CO_2) emissions from fossil fuel power plants make up the single largest source of greenhouse gas emissions (GHGs) in the United States.[13] While many policymakers, researchers, and activists concerned with the dangerous effects of climate change support policies and technologies that reduce or displace use of fossil fuels, the coal and oil and gas industries have proposed an alternative solution: to use technology to remove GHGs before or after burning fossil fuels in order to prevent their release into the atmosphere. Carbon dioxide emissions make up the largest contribution to global climate change of all GHGs, and this paper focuses on technologies developed to remove or reduce atmospheric CO_2 emissions from fossil fuels.[14] The various forms of this technology are commonly referred to as CCS, or Carbon Capture and Sequestration.

Carbon Capture and Sequestration (CCS):

The process of capturing man-made or anthropogenic CO_2 and permanently preventing its release into the atmosphere by storage underground in geologic formations.[15]

Investor-owned utilities, fossil fuel companies, and members of both major political parties have embraced public investment in CCS technology as a way to reduce climate change-causing GHG emissions while continuing to burn coal for electricity. In a carbon-constrained world, continued burning of coal is dependent upon capturing and permanently storing carbon. In the U.S., the federal government has contributed billions of taxpayer dollars toward CCS demonstration projects and tax breaks for a handful of CCS facilities. The customers of one investor-owned utility, Mississippi Power, are on the hook for over half of the $7 billion that the company has sunk into a single CCS coal plant that still isn't — and may never be — operational.[16] Despite these billions spent in public subsidies and decades of publicly-funded research, demonstration, and pilot projects, the goal of developing safe, scalable, commercially viable CCS technology has eluded the fossil fuel companies, government agencies, and public utilities that have pursued it.

The dismal success rate of CCS technology to date has not curbed the enthusiasm of many state governments, members of Congress, and several consecutive Presidents — both Democrat and Republican — for spending public dollars on large-scale CCS research, demonstrations, and pilot projects. As the 115th Congress and a new President take office and decide how to pursue energy objectives and where to allocate limited taxpayer dollars, now is a good time to consider whether continued or expanded public investment in CCS technology will ever return low-cost coal-fired electricity that safely removes and permanently sequesters associated carbon emissions.

Unfortunately, CCS technology faces both technological and economic obstacles that make public spending on CCS technology a poor investment of taxpayer dollars. From capture to transport to storage, CCS technology has proven itself to be expensive, inefficient, unreliable, and insecure, despite billions in public investment so far.

- The world's largest carbon storage demonstration projects face serious questions about their security and reliability.
- The most popular carbon utilization technology — enhanced oil recovery — does not permanently sequester carbon dioxide.
- Retrofitting power plants with carbon capture equipment reduces the plant's thermal efficiency to as low as 16%[17] and increases electricity costs.
- There is only one operational coal-with-CCS plant in the United States, despite billions in public investment and dozens of demonstration projects.[18]
- Coal plants with CCS are the most expensive form of energy generation. Most coal-with-CCS power plant projects are either defunct or too expensive to be competitive with other low-carbon energy sources.
- Increasing our nation's capacity to safely capture, transport, and store carbon dioxide at a scale large enough to have a positive impact on climate change would be prohibitively expensive.
- Deploying renewable energy solutions such as wind and solar generation, time-of-use pricing, and grid management technology will lead to a cheaper, cleaner energy future with far less public investment.

Even if coal companies and utilities were able to solve these major problems, large-scale adoption of CCS technology would only lead to increased reliance on mining coal. Not only is coal a nonrenewable resource that is already running out in the United States,[19] its use also requires continued coal extraction, which causes permanent damage to land and water resources that we rely on. Further, burning coal for electricity produces air pollution beyond GHG emissions. Even if CCS technologies were cost-effective, safe, reliable and scalable, continued investment in CCS technology would lock our nation into energy infrastructure that needlessly destroys the land, water, and quality of life of people who live nearby.

Instead of allocating more taxpayer dollars to CCS projects and tax credits that are unlikely to provide a return, policymakers should focus on promoting the renewable energy and grid management technologies that will allow the United States to put Americans to work implementing cleaner, cheaper renewable energy solutions that reduce CO_2 emissions, reduce electricity costs, don't damage the environment, and are proven to work.

STORAGE

Although several pilot projects have successfully sequestered small amounts of CO_2 for several years, there are still major concerns with the safety, security, reliability, and economic viability of sequestration projects. These concerns multiply when researchers consider the scale of carbon sequestration necessary to slow climate change. As Stanford geophysicists Mark Zoback and Steven Gorelick write, "The issue is not whether CO_2 can be safely stored at a given site; the issue is whether the capacity exists for sufficient volumes of CO_2 to be stored geologically for it to have the desired beneficial effects on climate change."[20]

Furthermore, the upfront infrastructure investments required to sequester enough carbon to meaningfully reduce atmospheric CO_2 concentrations are astronomical. There is little evidence that, once sequestered, carbon sinks will never experience any breaks, migration, leaks, or blowouts. And there is no internationally recognized or standardized system for monitoring and verifying that CO_2 sinks will keep greenhouse gases underground in perpetuity.

Examples of challenged carbon storage projects

Several carbon sequestration sites already exist around the globe, but even the most successful carbon sequestration demonstration projects have encountered unforeseen challenges related to the volume and pressure of CO_2.

In Salah, Algeria

As part of its ongoing research into the feasibility of CCS technologies, the U.S. Department of Energy developed a carbon sequestration demonstration site adjacent to a natural gas plant in central Algeria. The In Salah site is the second-largest industrial-scale sequestration demonstration project in the world. Researchers from the Lawrence Livermore National Laboratory in Livermore, Calif., found in 2014 that pressurized sequestered CO_2 at In Salah was moving quickly through rock formations in unpredicted ways. According to researchers, the pressure either fractured the rock or widened existing fractures, allowing CO_2

to migrate into denser "cap rock" — a geologic layer intended to prevent leaks to the surface. While no leaks to the surface were detected as of the 2014 report, "[i]t's pretty clear that the pressures were high enough to create new fractures," said Josh White, a leading scientist in the study.[21] CO_2 injections at In Salah were discontinued in 2011 just seven years after the project began sequestering carbon. According to pro-CCS think tank Global CCS Institute, the site's "future injection strategy is under review."[22]

Statoil, North Sea, Norway

The world's largest industrial-scale carbon sequestration demonstration project, while still operational, has had its own difficulties. Statoil of Norway operates the project, located 800 meters beneath the sea floor in the North Sea's Sleipner Field. Researchers have found fractures near the CO_2 storage site suggesting that sequestered carbon might someday be able to leak from its storage reservoir. The discovery of many large fractures in a few sites examined has scientists reconsidering how well-contained the Utsira reservoir really is. "We might have to appreciate that there is a much greater chance for some CO_2 to leak out," said Stefan Bunz, a marine geologist at the University of Tromsø in Norway.[23]

Denbury Resources, Mississippi, United States

CCS proponents often refer to played-out oilfields as ideal locations for carbon sequestration. But oilfield sequestration is not adequately regulated and is risky, as evidenced by a 2011 CO_2 "blowout" in Mississippi. Texas-based Denbury Resources paid one of the largest fines in Mississippi history after a series of eruptions of CO_2, oil, mud and brine. In one instance, a 2,000-foot-deep hole vented carbon dioxide, oil and drilling mud for 37 days. "So much carbon dioxide came out that it settled in some hollows," suffocating deer and other animals, as reported in the Mississippi Business Journal. More serious was an "underground blowout" in nearby Louisiana when area concentrations of carbon dioxide were so high that responders had to wear breathing apparatuses to keep from suffocating.[24]

These three sites illustrate the various risks and liabilities associated with carbon sequestration that have not been addressed by industry or government CCS researchers. Pumping enormous quantities of CO_2 underground at high pressure, aside from being a public health and safety hazard, is a dubious method of combating climate change. The challenges faced by these three carbon sequestration demonstration projects indicate that there are fewer safe underground carbon sequestration sites in the world than researchers have anticipated.[25] For example, researchers have identified played-out oilfields as ideal locations for carbon sequestration, in theory, because CCS companies can make use of existing pipeline and drilling infrastructure to bring down costs. In practice, though, Denbury's blowouts in Louisiana and Mississippi showcase the risks associated with using oilfields for CCS.

CO_2 injections can cause earthquakes that rupture carbon sinks

Domestic oilfields have already experienced the unintended consequences of deep underground material injections. The practice of injecting oil and gas drilling waste deep underground into "injection wells" has led to dramatic increases in seismic activity, a phenomenon that has been well-documented in Oklahoma, Texas, Ohio and Pennsylvania.[26]

A pair of Stanford University geophysicists have warned that pumping enormous volumes of carbon dioxide into the ground under pressure is likely to do the same thing, adding that CCS-caused earthquakes near carbon sinks like In Salah or Sleipner could exacerbate fractures or rupture the seal that prevents CO_2 from leaking. "Our principal concern," the researchers write, "is not that injection associated with CCS projects is likely to trigger large earthquakes; the problem is that even small to medium earthquakes threaten the seal integrity of a CO_2 repository."[27] A ruptured carbon sink has negative effects for atmospheric CO_2 concentrations, and, depending on pressure and location, could be a significant safety hazard.

Pressurized carbon sinks present liability challenges

Once carbon is sequestered, pressurized underground carbon sinks are intended to exist in perpetuity — on the time scale of millennia. While there are serious questions about whether or not CO_2 will remain sequestered for this long without leaking into the atmosphere, additional questions arise concerning the safety of a global network of pressurized underground CO_2 storage reservoirs. The fossil fuel industry has realized the liability problems that could arise from owning such a network, and has begun to push legislation in U.S. states that shifts liability from CCS companies to the public.

Several states have already passed laws providing for the state to assume long-term liability for sequestered CO_2. Illinois, Indiana, Louisiana, Montana, North Dakota and Texas have enacted various versions of laws that shift liability for leaks, losses, and damages from sequestered carbon from the corporations that profit from them to the state taxpayers. Illinois enacted a law in 2007 to assume the title to and liabilities associated with CO_2 injected by the FutureGen Project.[28]

Carbon storage at scale is cost-prohibitive

Before it is pumped underground, CO_2 has to be captured, compressed, and transported to a sequestration site for injection. When burning coal to generate electricity, two to three times more CO_2 is emitted than coal is burned, presenting enormous challenges for shipping and storing.[29]

By train, moving waste CO_2 from source (e.g. a coal plant) to injection site would require more pressurized tank cars than are needed to move the corresponding amount of coal from mine to plant. The Global CCS Institute estimates that the pipeline network necessary to transport waste CO_2 at the scale necessary to avoid global warming of two degrees Celsius must be similar in size to what exists now for the entire domestic oil and natural gas industry, and must be constructed within 30 to 40 years.[30] It is hard to imagine the upfront costs of building such infrastructure, notwithstanding the challenges posed by permitting, property rights, water quality, and public safety concerns. The monumental nature of this task is stated succinctly by Vaclav Smil in *Energy at the Crossroads*, *"Sequestering a mere 1/10 of today's global CO_2 emissions (less than 3 gigatons of CO_2) would thus call for putting in place an industry that would have to force underground every year the volume of compressed gas larger than or (with higher compression) equal to the volume of crude oil extracted globally by the petroleum industry whose infrastructures and capacities have been put in place over a century of development."*[31]

Although there is not an intrinsic problem with public investment in climate solutions, the current framework for public investment in CCS projects is a thinly-veiled corporate giveaway. In fact, fossil fuel companies' reluctance to 1) invest private capital in CCS projects and 2) retain liability of carbon sinks underscores the uncertainty and extreme risk associated with carbon capture technology. The public first subsidizes — through tax credits, federal grants, and ratepayer cost recovery — CCS projects built by fossil fuel companies and investor-owned utilities, then assumes liability once the projects are complete. Utilities profit handily, even when projects experience cost overruns in the billions of dollars, and have little incentive to ensure that carbon sinks are safe and reliable into the future.

UTILIZATION

"Utilization" is an often-cited alternative to sequestering CO_2. In theory, if waste CO_2 from burning fossil fuels is tied up in products or materials, then it can't contribute to the atmospheric concentrations of CO_2 that cause global climate change. Unfortunately, the scale of CO_2 emissions easily oversupplies the existing market for waste CO_2 utilization, depressing the price of waste CO_2 and further limiting marketable solutions. Far and away the most common large-scale "utilization" technology for captured CO_2 is enhanced oil recovery (EOR), whereby waste CO_2 is pumped into aging oil wells to boost production. There are several problems with EOR, including questions about whether or not the practice successfully reduces atmospheric CO_2 at all.

Enhanced Oil Recovery is not carbon sequestration

Injecting carbon dioxide to increase productivity of an aging oil well is a decades-old technology, first attempted in Texas in 1972,[32] "several decades"[33] before any consideration of geologic carbon sequestration. EOR is an established technology for boosting oil production and is one of the few scalable value-added uses of carbon dioxide. An operator in the Weyburn oil field of Saskatchewan, Canada, intends to use EOR to extract "130 million barrels of oil that might otherwise have been abandoned."[34]

Enhanced oil recovery is not, however, an established technology for permanently sequestering CO_2 underground. As stated above, aging oil fields are not ideal locations for carbon sequestration. Old or abandoned oil and water wells represent vulnerabilities that can allow sequestered CO_2 to leak (or explode) back into the atmosphere. EOR pumps CO_2 into underground rock formations with dozens, or even thousands, of holes in the form of oil wells, in addition to fractures or fissures that occur naturally or are induced by the pressures of CO_2 injection.

"All these applications leak," said oilman Thomas Blanton, "Carbon dioxide sequestration in an oil field is science fiction standing squarely on the shoulders of a myth."[35]

Despite these uncertainties about the long-term benefits of CO_2-EOR in reducing atmospheric CO_2, Congress has instituted a federal tax credit to promote the practice, and the Department of Energy continues to fund carbon capture demonstration projects for which EOR is the sole method of sequestration. The Internal Revenue Service provides a tax credit of $10 per ton of CO_2 used in EOR applications without requiring well operators to prove that the CO_2 has not leaked. Senator Heidi Heitkamp (D-ND) has introduced a bill in Congress with broad bipartisan support to increase the tax credit to $35/ton.

Enhanced Oil Recovery does not decrease CO_2 emissions

EOR fails to sequester CO_2 in two ways. First, as mentioned above, oil fields leak. Once CO_2 has been used in EOR, there is no evidence to suggest that the waste CO_2 remains sequestered safely underground. Denbury Resources' EOR blowouts in Mississippi and Louisiana are dramatic examples of the inadequacy of oilfields as carbon sinks. But CO_2 is a gas, and blowouts aren't the only method by which it can leak. CO_2 can find multiple escape pathways due to chemical reactions with water, rocks and cement from abandoned wells. "Even if [CO_2] doesn't escape to the Earth's surface, there are concerns that it may leak into groundwater drinking aquifers," said Penn State petroleum engineer Li Li, who studies CO_2 migration underground. "If this plume of carbon dioxide-saturated brine reaches an abandoned well, it will react with the cement," said Zuleima Karpyn, another Penn State petroleum engineer working on the project. "This may open up cracks in the cement depending on the conditions, which would increase the likelihood of CO_2 escaping."[36]

Even if CO_2 injected underground for EOR stayed put, EOR fails to reduce atmospheric greenhouse gas emissions in another way: EOR trades waste CO_2 from a power plant for carbon emissions from additional oil production and use. Using CO_2 to extract additional fossil fuels that would have otherwise stayed in the ground does not result in a net reduction in atmospheric GHG emissions.

In 2009, a Denbury Resources petroleum engineer calculated that EOR can keep more CO_2 underground than a barrel of oil will put back into the atmosphere. He estimated that EOR reduces overall emissions by 24%, meaning a barrel of recovered oil puts 0.42 metric tons of CO_2 into the atmosphere, but 0.52 to 0.64 metric tons are injected underground recovering it.[37] This slim margin of error assumes no leaks in the system, and changes depending on both the geology and oil quality of different deposits. At best, the net carbon benefits of EOR are slim and marginal. At worst, EOR causes a net increase in GHG emissions.

In fact, Carnegie Mellon researchers in the same year studied CO_2-EOR systems in five different basins and found that, in some cases, capturing waste CO_2 for use in EOR produced more GHG emissions than not capturing the CO_2 in the first place.[38]

EFFICIENCY

Installing carbon capture technologies onto coal-fired power plants reduces the thermal efficiency of those plants, thereby increasing the cost of electricity. CCS technology consumes lots of energy on its own in order to capture, compress, transport, and sequester carbon, creating a vicious cycle often referred to as the "efficiency penalty." Capturing and sequestering carbon demands additional energy, which in turn requires more capture and sequestration, demanding more energy.

The efficiency penalty reduces the efficiency of CCS-equipped fossil fuel generation: a CCS coal plant has to burn more coal for each megawatt of power it provides to the grid. There are two negative effects of requiring more fuel to create the same amount of energy. First, CCS will increase electricity prices, since coal plants need more fuel without an increase in revenue from selling more power. Second, CCS perpetuates coal extraction, which is itself an environmentally destructive process with externalized costs on water, land, and public health.

Advanced non-CCS coal-fired power plants operate at approximately 38% thermal efficiency, meaning 38% of the energy in coal is turned into electricity that consumers use. Most current scientific literature rates the thermal efficiency of coal plants with installed carbon capture technology at 26%. According to researchers at the University of Michigan, however, most of the current literature fails to consider the feedback effects (efficiency penalty) created by CCS systems. By taking these feedback effects into account, UM researchers estimate thermal efficiency for coal plants with carbon capture at closer to 16%, noting that engineers have noticed higher-than-expected energy penalties on CCS test projects coming online.[39]

"To capture CO_2, you need to generate more energy. To get this energy, you burn more coal, which creates more CO_2 that needs to be captured. So there's the loop that's happening that needs to be accounted for," explained Sarang Supekar, postdoctoral mechanical engineer and principal author of the Michigan study.[40]

"To us this means policy makers need to stop wasting time hoping for the technological silver bullets to sustain the status quo in the electric sector and quickly accelerate the transition from coal to renewables, or possibly, natural gas power plants with CCS," said Steve Skerlos, co-author of the study and Michigan professor of mechanical engineering.[41]

The Michigan researchers also studied the cost of electric power from CCS-equipped coal-fired power plants compared with the cost of power from other sources using the levelized cost of electricity (LCOE),[42] a common metric for comparing power costs across sources. Their analysis included mass and energy feedbacks in state-of-the-art CCS-equipped pulverized coal-fired generators and potential quality considerations for safe and reliable transportation and sequestration of CO_2. The efficiency penalty alone accounted for 5.3-7.7 US¢ per kilowatt hour (kWh).[43] Add this to an estimated 8.4 US¢/KWH for coal-fired power plants without CO_2 capture technology, and it is clear that CCS-equipped coal-fired power is considerably more expensive than other low-carbon or zero-carbon sources of electricity.[44]

At SaskPower's Boundary Dam—a Canadian coal-with-CCS generation facility—the carbon system is a "voracious consumer" of the electricity generated by the plant. Of 150 MW of capacity, 30 MW is consumed by the carbon capture system and an additional 15-16 MW are needed to compress CO_2. Approximately 31% of the power generated by the project is used for CCS, leaving 69% to be distributed to electricity consumers.[45]

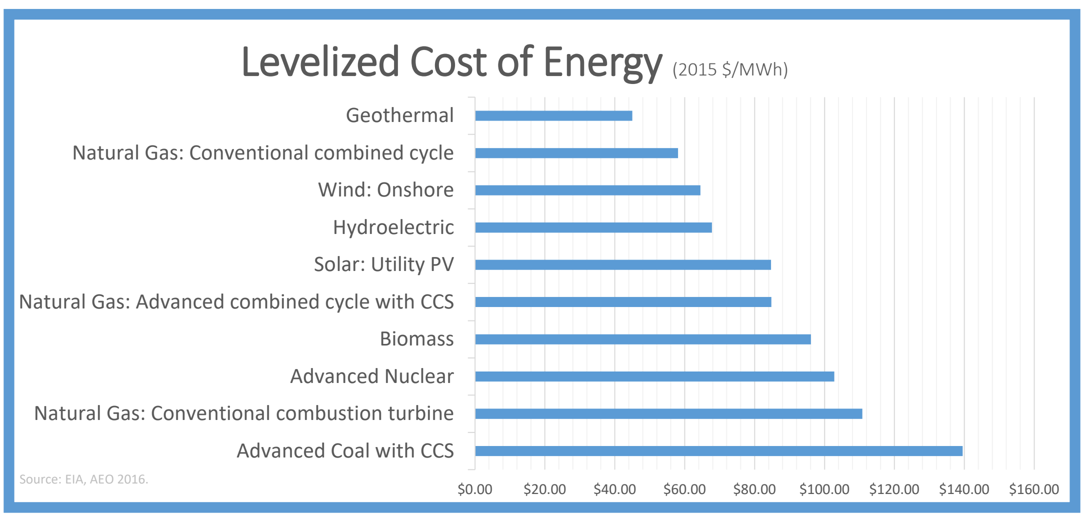
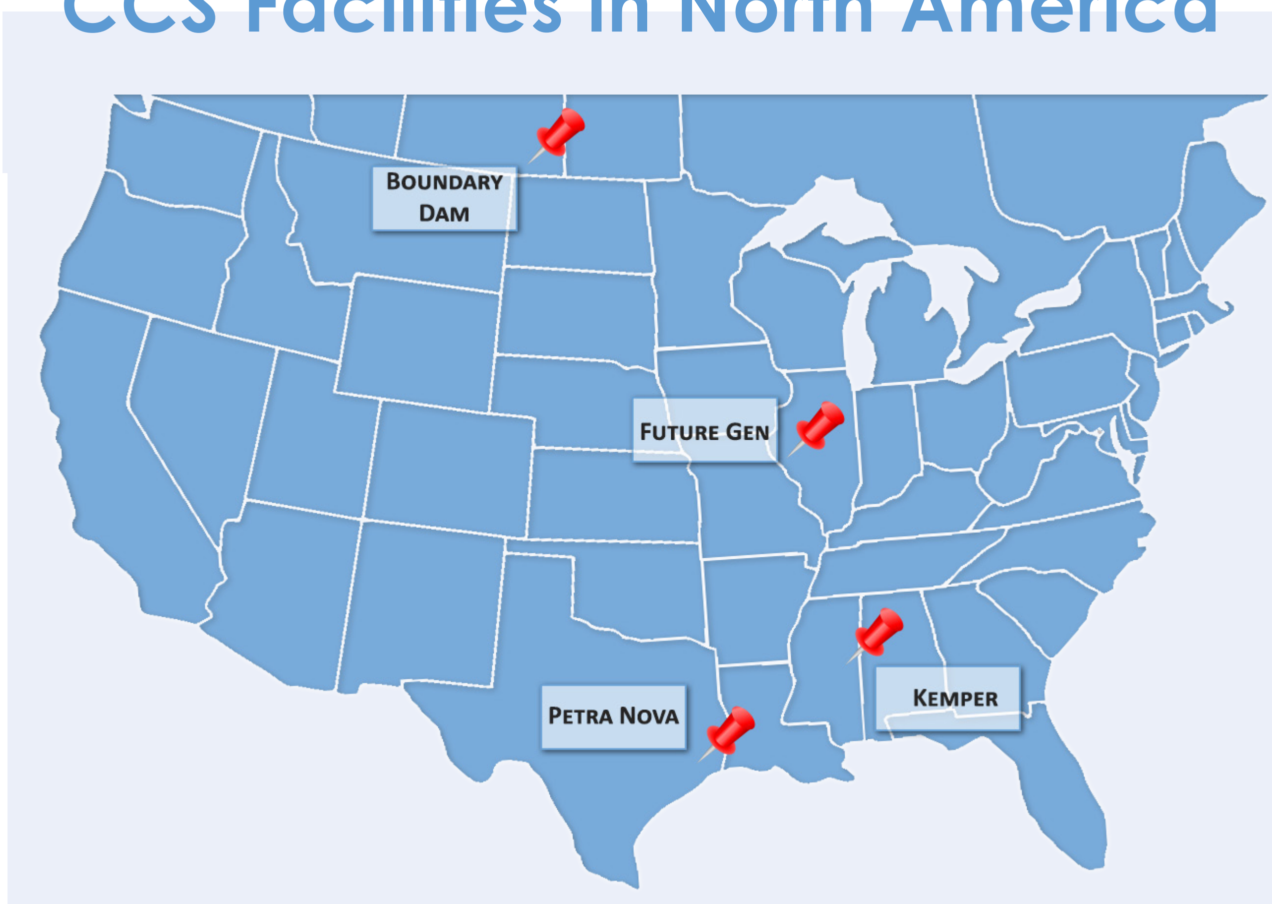


Figure 1. Advanced coal with installed carbon capture equipment is the most expensive form of low-carbon energy, more than double the $/MWh of new onshore wind, according to data from the Energy Information Administration's Annual Energy Outlook 2016.

TRACK RECORD

Current CCS facilities -- either new electrical generation or existing power plants retrofitted with carbon capture technology -- have experienced failed technology, cost overruns, and abuses of public dollars. Below is a brief overview of four coal-with-CCS projects in the U.S. and Canada, one recently opened, one built and operating, one suspended, and one significantly delayed.

CCS Facilities in North America



Petra Nova, Texas

The Petra Nova project outside of Houston, Texas, reportedly captures 90% of the CO_2 from a 240MW flue gas slipstream on a larger coal-fired power plant. The gas is sold for use in EOR (see "Utilization") and transported through a pipeline to oilfields in the Permian Basin. According to the project's backers, Petra Nova is profitable as long as oil prices stay above $50 per barrel.[46] Petra Nova consists of new CO_2-capturing scrubbers and a CO_2-transporting pipeline attached to an existing power plant. The project makes use of post-combustion capture technology and supplements its income by selling CO_2 for use in EOR, much like SaskPower's Boundary Dam in Canada (see below).

The plant is owned in a 50-50 partnership between New Jersey-based NRG Energy Inc. and Japanese-owned JX Nippon Oil & Gas Exploration Corporation, both of which invested $300 million into construction. The remainder of the $1 billion sticker price was covered by guaranteed loans from the Japanese government and $190 million in U.S. Department of Energy

Credit: Roy Luck, https://www.flickr.com/photos/royluck/5518927574. Creative Commons 2.0

Figure 2. The W. A. Parish power plant outside Houston, Texas. This 3700 MW facility has installed a scrubber to capture CO2 emissions from 240 MW of the plant's capacity.

grants.[47] The CO_2-EOR system in place at Petra Nova is vertically integrated; the owners own oil drilling operations in the Permian Basin and thereby supplement the plant's income with oil revenue when oil prices are high.

By reaching the operations phase, Petra Nova is more successful than many other CCS plants. But the project is barely breaking even for its owners, who are lukewarm about the finances: "At $50-dollar oil it's very challenging," NRG CEO Mauricio Gutierrez told Forbes.[48] NRG, in its 2016 10-K filing with the Securities and Exchange Commission, wrote down its investment in Petra Nova by $140 million — almost half of the $300 million that the company invested.[49] NRG and JX Nippon provided only 60% of the capital required to build the plant, with the rest coming from government grants and guaranteed loans. Government subsidies for the plant are poised to grow as the plant makes use of the 45Q tax credit, which provides $10 to the owners for every ton of CO_2 sold for EOR. Some members of Congress have proposed increasing the tax credit to $35 per ton of sequestered CO_2. At 5,000 tons of captured CO_2 per day, U.S. taxpayers would be paying NRG and JX Nippon almost $64 million every year.

It is also worth noting that, while the companies claim to be capturing 90% of the CO_2[50] from a 240 MW flue gas slipstream on the W.A. Parish coal plant, the unit in question produces 610 MW of coal-fired electricity,[51] while the "gargantuan" Parish plant actually produces some 3700 MW of electricity.[52] At maximum capacity, Petra Nova is capturing about 35% of the CO_2 produced at the Parish plant. Further, the carbon capture equipment is powered by a brand new 75 MW natural gas combined cycle plant built for the purpose of side-stepping the "efficiency penalty." That's right: to capture 90% of the CO_2 emissions from 240 MW worth of coal plant exhaust, NRG and JX Nippon built a new 75 MW gas plant.

SaskPower Boundary Dam 3, Saskatchewan

Just north of Montana's border with Canada lies the Boundary Dam Unit 3, part of an existing coal-fired power plant complex operated by SaskPower, a provincially owned and operated electric utility. Boundary Dam 3 is a 120 MW coal boiler with a post combustion[53] CCS facility that began operating in October 2014. In late 2015, after the government publicly claimed that the project was capturing 90% of the plant's carbon, a Saskatchewan Assemblywoman, Cathy Sproule, unveiled confidential documents indicating the plant's CCS functions were working at only 45% of capacity. One memo identified eight problem areas that could take a year and a half to fix. The $1.1 billion project "is now looking like a green dream," according to the New York Times.[54] The plant has been plagued by multiple shutdowns and has fallen short of its emissions targets, facing unresolved problems with its core technology. Costs have soared, requiring tens of millions of dollars in new equipment and repairs, according to the Times.

"One shutdown last spring to clean and replenish the chemical cost $17 million (CAD)…. The repeated shutdowns have caused SaskPower to miss multiple CO_2 deliveries to Cenovus Energy (CE), the Canadian oil company that signed a 10-year contract with the utility to buy most of the gas…. SaskPower has had to pay $7 million in penalties for not delivering carbon dioxide to CE, offsetting most of the $9 million (CAD) in payments received."

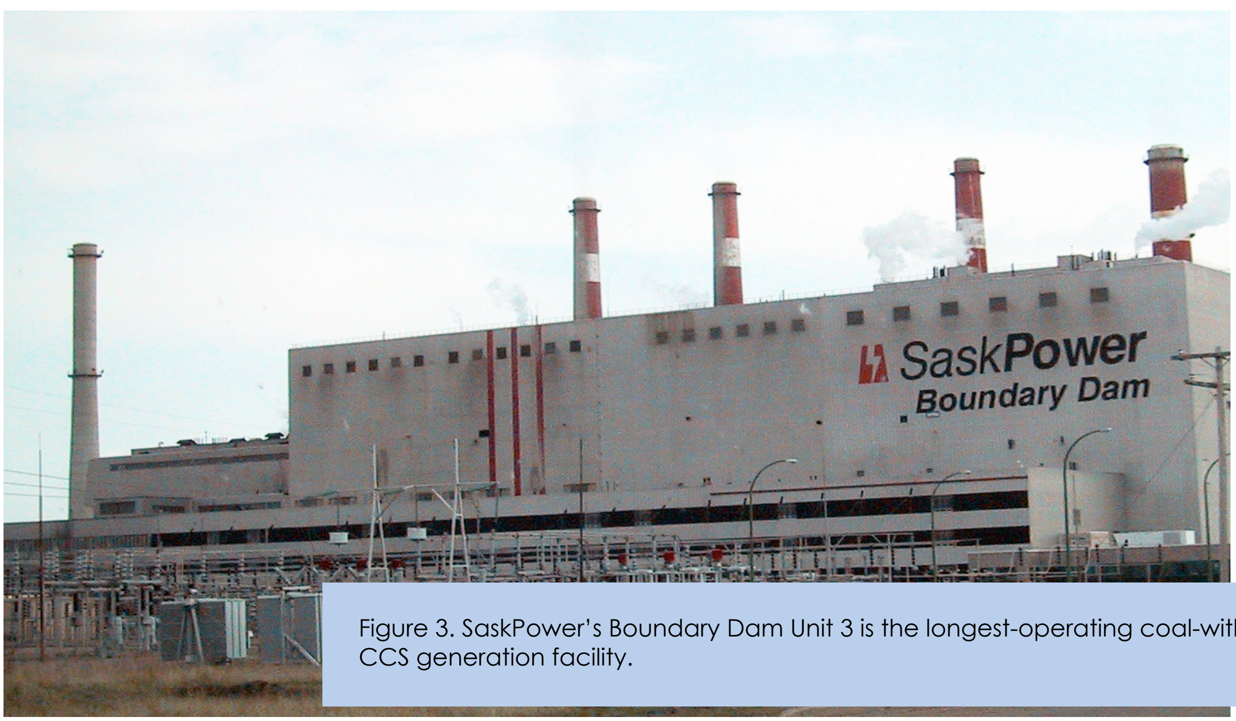


Figure 3. SaskPower's Boundary Dam Unit 3 is the longest-operating coal-with-CCS generation facility.

FutureGen, Illinois

Located in southern Illinois coal country, FutureGen was a 12-year unsuccessful effort to capture CO_2 from a coal-fired power plant. The original goal of FutureGen, a $1.7 billion public-private venture, was to operate a 275 MW coal-fired power plant that would produce electricity and hydrogen with near-zero emissions and cost less than 10% more to ratepayers than non-sequestered systems by 2020. The project was backed by President George W. Bush in 2003. Before the end of Bush's second term, the project was so mismanaged and so far over budget that it was eventually dubbed "NeverGen" by energy experts. The Bush Administration pulled the plug on its efforts in early 2008.[55]

In 2010, the Obama Administration used funds from the American Recovery and Reinvestment Act to revive the project as FutureGen 2.0, this time intended to retrofit an existing Illinois coal plant to capture 90% of its carbon pollution. After five years and a little over $200 million in federal investment, the Administration concluded that there was not time to complete the project before federal funding authorization expired in September 2015. In the end, the federal government sunk $210 million into FutureGen 2.0. The coal industry and the state invested $25 million. The project never secured additional private financing.

Credit: User XTUV00100. https://commons.wikimedia.org/wiki/File:Kemper_Project_Construction.png. Creative Commons 2.0

The Kemper Energy Facility in Mississippi is behind schedule by almost a full year and has cost $7 billion so far—almost quadruple its initial budget estimate.

Kemper County Energy Facility, Mississippi

In December 2006, Mississippi Power (owned by multi-state utility Southern Company) announced a $1.8 billion coal-with-CCS facility in southwest Kemper County. Today, the plant has yet to produce electricity from carbon sequestered coal. In the meantime, the cost of the project has nearly quadrupled to over $7 billion. In May 2016, the Securities and Exchange Commission launched an investigation of the cost overruns and delays of the project.

The Kemper plant uses a pre-combustion carbon capture system. Half the plant is fed by natural gas, the other half by coal. On the coal side, the Kemper facility first converts lignite coal to gas, and then strips out CO_2 and other pollutants prior to burning the fuel.

An arguably bigger question than when the plant will open is how much Mississippi's ratepayers will be forced to pay to cover billions of dollars in cost overruns. The first rate increase related to Kemper went into effect in April 2013, increasing customers' base rates by 15%[56] long before the project ever produced electricity or sequestered carbon. This was only possible because Mississippi's state government passed special legislation to allow Mississippi Power to charge ratepayers for the plant during construction.[57] The law was signed by Governor Haley Barbour, who was Southern Company's chief lobbyist before being elected Governor and "aggressively promoted" the Kemper facility both before and after election.[58]

Additional legislation in 2013 further enabled the Mississippi Public Service Commission (PSC) to approve ratepayer recovery for the facility and made up to $1 billion in bonds to cover Kemper eligible for rate-recovery.[59] Mississippi Public Service Commissioner Cecil Brown said, "I can't imagine that a regulator would approve this. I can't imagine a company would approve this."[60] Mississippi regulators now face the "awful task" of "not pushing the utility into bankruptcy while determining how much electricity customers, taxpayers and investors should pay for the billions of dollars in cost overruns."[61]

Additional public subsidies are promised or pending in Congress for the plant's use of CO_2 in EOR. Legislation introduced in Congress by Representative Mike Conaway (R-Texas) would create $789 million in tax credits for Kemper over the next decade, based on a per ton credit for sequestered carbon. If Rep. Conaway's bill becomes law, U.S. taxpayers will pay $4.5 billion to Southern Company over Kemper's proposed 40-year life span.

COST

Despite repeated failures and financial catastrophes, federal and state governments and investor-owned utilities have spent taxpayer and ratepayer money on CCS projects for decades, always with the same argument: the technology is expensive now, but will be competitive over time as prices drop.

Carbon capture cannot currently compete without government subsidies. A recent *Epoch Times* article points out, "Proponents and opponents generally agree that CCS is not yet economically viable."[63] Proponents of CCS argue that the decades of public investment are warranted, and that more is needed for the technology to become viable and commercially competitive: "Advancing CCS technology still requires more government support to get off the ground," said Massachusetts Institute of Technology senior research engineer Howard Herzog. "Markets for CCS have not been sufficient to do that, so you also need what I call a 'technology push' or government programs to bridge the gap," he explained in a July 2016 Energy & Environment interview.[64]

In order to provide this "technology push," Congress has given the U.S. Dept. of Energy (DOE) $7 billion for CCS activities since fiscal year 2008, according to the Congressional Research Service.[65] A Taxpayers for Common Sense report found that companies using CCS technology have also already received tax credits worth more than $2.5 billion over the next 10 years.[66] The new Administration and Congress have expressed interest in further subsidizing the technology.

Proposing to "bridge the gap" with government funding assumes that the price of CCS will come down enough to make it competitive in an open market. This is a central talking point of CCS proponents, who point out the startling rate at which prices for solar and wind generation have dropped as technology has improved. Steve Clemmer of the Union of Concerned Scientists points out some fundamental differences between CCS and renewable technology:

> *"While it is reasonable to expect that CCS costs will come down, the question is how much and over what time period? Like nuclear power plants, CCS projects tend to be very large, long-lived construction*

projects that use a lot of concrete and steel, and equipment that is unlikely to be mass-produced in the way more modular technologies like wind turbines and solar panels are manufactured and installed over a much shorter period of time."[67]

There is no evidence to suggest that the federal government's ballooning CCS investment will pay off. According to leading energy analysts, including the Energy Information Administration (EIA), electricity from coal-fired power plants with installed CCS simply will not compete in an open market with renewable energy sources or other fossil fuels with installed CCS:

"Several recent studies project the cost of coal with CCS to be much higher than many other low and zero carbon technologies. For example, the [EIA's] projections from Annual Energy Outlook 2016 show costs for coal with CCS plants in 2022 that are 2-3 times higher than the cost of new onshore wind, utility scale solar, geothermal, and hydropower projects, not including tax incentives . . . While EIA projects the costs for coal with CCS plants to decline ~10 percent by 2040, they project the costs for other low carbon technologies to fall by similar or even greater amounts."[68]

The best case scenario resulting from further public investment in coal with CCS technology is decades of continued reliance on coal mining and sky-high electricity prices. The 16% thermal efficiency[69] of electricity produced by coal-with-CCS means twice as much coal will be mined to generate the same amount of power that we use today.[70] The cost of mining coal is set to increase over time as the thickest, most accessible coal reserves are depleted — a process that is already under way.[71] The billions of taxpayer dollars invested into research, demonstration and commercialization of coal-with-CCS technology will pay off in the form of an energy grid designed to hit Americans in the pocketbook, hamstring our nation's economy, and continue damage to land, water and public health caused by coal extraction.

Subsidizing Carbon Capture

Despite this, policymakers on both sides of the aisle and at multiple levels of government are proposing to double down on CCS. Numerous prominent Republicans, including President Trump and Senate Majority Leader Mitch McConnell have consistently supported subsidies for CCS technology, despite the 2016 Republican platform's claim that it supports "development of all forms of energy that are marketable in a free economy without subsidies including coal, oil, natural gas, nuclear power, and hydropower."[72] Nevertheless, it appears that numerous Congressional Republicans actively support legislation to continue and expand subsidies for CCS. Coal country Democrats and climate hawks are also on board with CCS subsidies.[73]

Further, former Texas Governor Rick Perry, now Secretary of Energy, has his own history of supporting public subsidies of CCS projects. In 2009, Perry signed a bill providing tax incentives to the Texas Clean Energy Project, a 400 MW coal gasification with CCS project that ultimately missed multiple deadlines, doubled its budget to $4 billion, lost its DOE funding (after receiving $167 million), and will most likely be officially abandoned in the near future.[74]

Several members of Congress are proposing to open the flood gates for even greater subsidization of the technology by extending, increasing, and removing the cap on an existing tax credit for every ton of CO_2 captured and sequestered.

The CCS tax credit grew out of the "Emergency Economic Stabilization Act of 2008," also known as the Wall Street bailout. It is known as 45Q, named for the section of the tax code where it is found. Its purpose was to advance a CCS industry in the U.S. and keep carbon out of the atmosphere, which it did by paying companies $20 for each ton of CO_2 captured and stored underground and $10 for CO_2 captured for EOR. It was capped at 75 million credits, which the U.S. Treasury Department estimates will expire by 2019.[75] Rep. Mike Conaway (R-Texas) sponsored a bill in the 114th Congress (H.R. 4622) that would make the 45Q tax credit permanent and steadily increase it to $30 between 2016 and 2025 for both EOR and underground storage. Others have advanced bills that would retain a cap number of credits, but increase the subsidy over a period of years (for example, S. 3179 sponsored by Sen. Heidi Heitkamp, D-North Dakota).

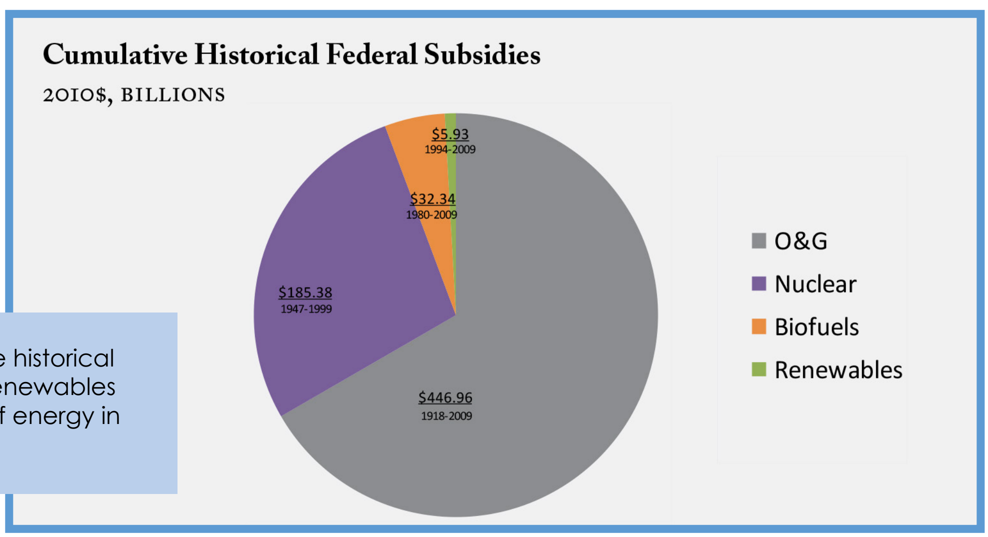


Figure 6. Cumulative historical federal subsidies. Renewables lag all other forms of energy in federal support.

"Policy Parity" — the Policy Price of CCS v. Renewables

Proponents of CCS use the term "policy parity" to justify government spending on CCS tax credits and demonstration projects. The term is intended to raise the issue of federal tax credits supporting installation and implementation of renewable energy. What CCS proponents do not acknowledge, though, is that fossil fuel generation receives government subsidy and support at rates far higher than renewables, even before the billions spent on CCS enter the equation.

An analysis by Management Information Services for the Nuclear Energy institute (NEI) found that 70% of the energy subsidies handed out between 1950 and 2010 were given to the oil, natural gas, and coal industries, compared to only 9% for renewables like wind and solar.[76] A 2011 DBL Investors analysis calculated that the average annual federal subsidy for both oil and gas ($4.86 billion per year) and nuclear energy ($3.5 billion per year) dwarfs the amount invested in cleaner renewable energy ($370 million.) DBL chose to focus its analysis on federal investment in the critical early decades of each emerging technology, and found that "renewable subsidies trail all" other federal investment in energy sectors "during the first 30 years of those subsidies' existence."[77]

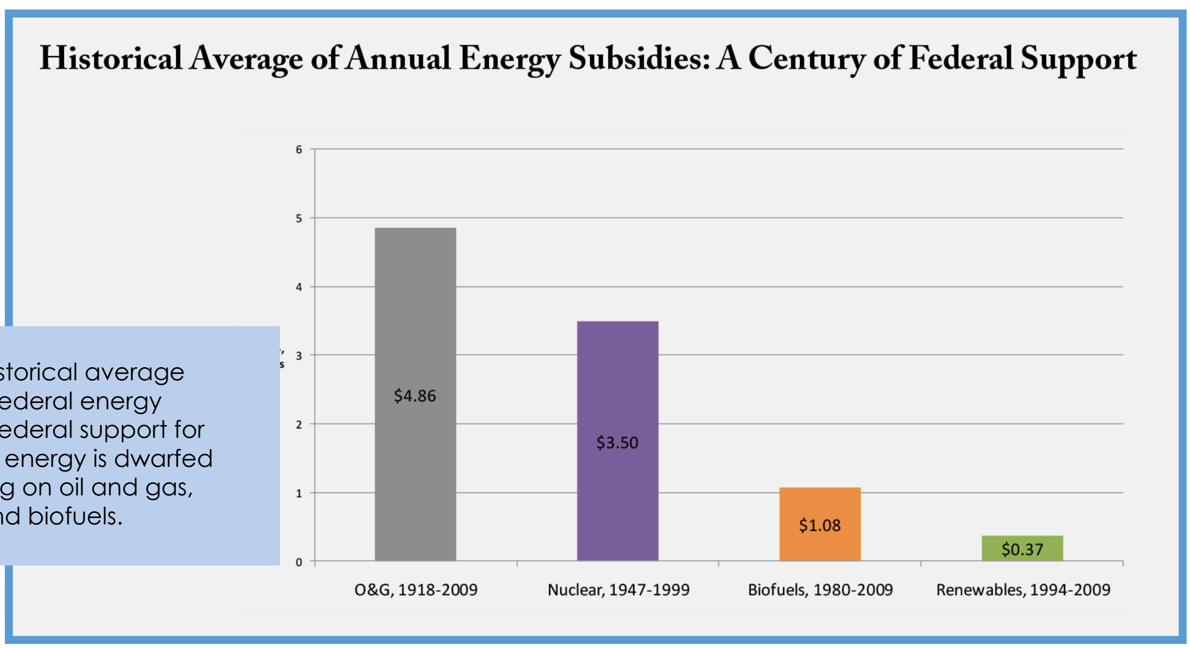


Figure 5. Historical average of annual federal energy subsidies. Federal support for renewable energy is dwarfed by spending on oil and gas, nuclear, and biofuels.

Charts on pages 24 and 25 used with permission from *What Would Jefferson Do?* by Nancy Pfund and Ben Healey, DBL Investors http://www.dblpartners.vc/resource/what-would-jefferson-do.

CONCLUSION

Decades of public investment in CCS have failed to advance the technology to a point where it can compete with rapidly growing and emerging clean energy sources. Critical questions about the safety, security, and technology of long-term sequestration also remain unanswered.

The billions of dollars in public investment spent on CCS demonstration projects have so far shown only that the technology is expensive, inefficient, unreliable, and insecure. Carbon storage sites around the world have achieved mixed results -- some have leaked or exploded, while others have discontinued storage operations due to unexpected cracks and migration from the pressurized CO_2, suggesting that there simply aren't as many geologic formations appropriate for CO_2 storage as proponents have estimated. Carbon utilization technologies have not appeared at scale, with the exception of EOR, an oil extraction technique that may actually cause a net increase in GHG emissions. Coal plants with CCS are fundamentally inefficient, which drives up costs enough to make coal-with-CCS one of the most expensive forms of energy on the market. In addition, after decades of investment, there simply aren't very many examples of operational power plants with carbon capture technology. While there is a long track record of failed or abandoned CCS projects, there is only one operational facility in the United States.

Proponents of CCS argue that without baseload coal from plants designed to remove and store carbon, essential global climate goals cannot be realized. However, technological solutions to address balancing, dispatching, and storing renewables on the electric grid are well within reach. In 2016, U.S. scientists published an analysis demonstrating that a transition to a reliable, low-carbon electrical generation and transmission system can be accomplished with commercially available technology within 15 years.[78]

Carbon capture and sequestration technology is a distraction from the affordable clean energy future that we have the opportunity to build. Every dollar spent on CCS is a dollar spent on already outdated technology, and is a dollar not available for investment in cheaper, cleaner, and simpler energy solutions. Federal investment in CCS is a poor use of public dollars. It is time to focus public and private capital resources and public policy on affordable and technologically demonstrated clean energy sources that will result in a market-based, low-carbon energy future with cheaper bills, cleaner air, and a reduced threat of catastrophic global climate change.

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As the global effects of climate change become more apparent, both markets and governments around the world are working to reduce greenhouse gas emissions. State and federal politicians, the coal industry, and even some environmental organizations support Carbon Capture and Sequestration (CCS) technology as a strategy to continue to generate electricity with coal in a carbon-constrained future.

The industry's hope that coal can provide electricity while decreasing carbon emissions without drastically raising electricity costs and causing environmental damage is simply too good to be true. CCS technology faces both technological and economic obstacles that make public spending on CCS technology a poor investment of taxpayer dollars. From capture to transport to storage, CCS technology has proven itself to be expensive, inefficient, unreliable, and insecure, despite billions in public investment so far.

WORC

Western Organization of Resource Councils

Grassroots Leadership & Action