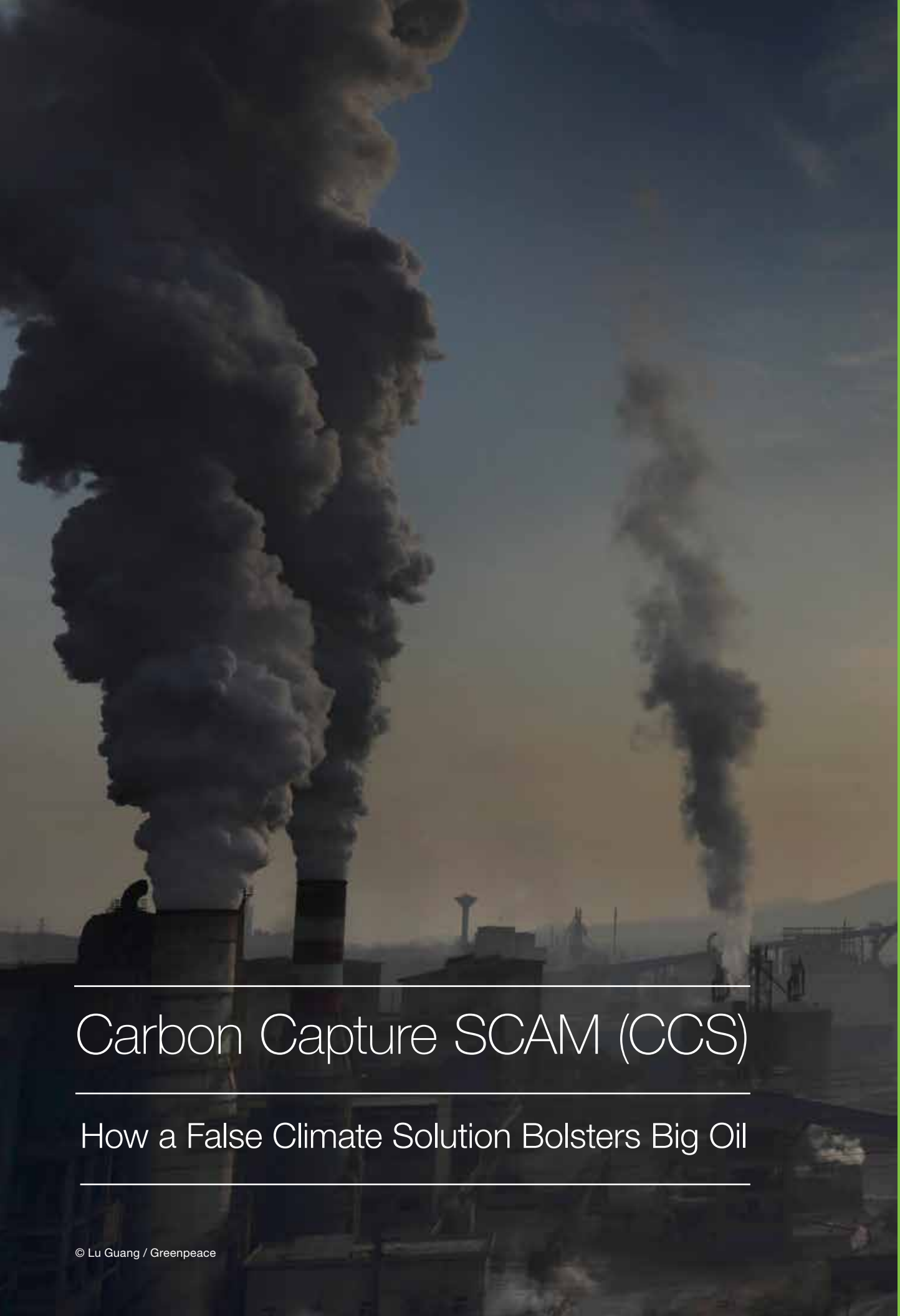

Carbon Capture SCAM (CCS)

How a False Climate Solution Bolsters Big Oil

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Acronyms and Abbreviations:

ARRA – American Recovery and Reinvestment Act
CBO – Congressional Budget Office
CCPI – Clean Coal Power Initiative
CCS – Carbon Capture and Sequestration (or Storage)
CC-EOR – Carbon Capture for Enhanced Oil Recovery
CDM – Clean Development Mechanism
CO2-EOR – Enhanced Oil Recovery with CO2 Injection
DOE – Department of Energy
EGU – Electricity Generating Unit
EIA – Energy Information Administration
EOR – Enhanced Oil Recovery
EPA – Environmental Protection Agency
E[R] – Energy [R]evolution report
GHG – Greenhouse Gas
IEA – International Energy Agency
IGCC – Integrated Gasification Combined Cycle
KW – Kilowatt
Kwh – Kilowatt Hour
mtpa – megatons per annum
MW – Megawatt
MWh – Megawatt hour
NEORI – National Enhanced Oil Recovery Initiative
TCEP – Texas Clean Energy Plant
TWh/a – Terawatt hours per annum

Tragically, the captured CO2 collected via carbon capture will become a catalyst for even more CO2 pollution.

Introduction

Human-caused, global climate disruption demands we quickly phase-out the burning of fossil fuels as an energy source.[1] It turns out that turning on the lights does not require incessantly extracting, processing and transporting combustion fuels that produce unwanted toxins, pollution and waste. The Greenpeace Energy [R]evolution analysis (E[R]), as well as many others, demonstrates there is a pathway to a renewable energy economy in time to stop the worst impacts of global warming.[2]

Many politicians and industry leaders, however, refuse to let go of the combustion economy, and waste valuable time and resources on false solutions. Nothing epitomizes destructive political procrastination on climate more than promoting carbon capture for coal-fired power plants.

The CCS myth posits that the economy could continue to burn fossil fuels without the harmful effect of global warming. CCS is regarded as the last hope for the coal extraction industry, even as the industry is loath to acknowledge the need to reduce carbon pollution. Electric utilities don't really care if CCS works or not, but they are willing to take public money to see if it does.

Oil companies have proven a strong ally of carbon capture because it provides them with a ready source of subsidized CO2 that they can inject into reservoirs to extract more oil. Support for CCS delays the transition to renewables. In no uncertain terms, political and financial support for carbon capture hurts the climate. Tragically, the captured CO2 collected via carbon capture will become a catalyst for even more CO2 pollution.

Burning fossil fuels for electricity is the number one source of anthropogenic carbon dioxide, the most predominant greenhouse gas and most problematic climate pollutant over the long term.[i] Burning coal is the number one source of CO2 from the electricity sector.[3] The proposed carbon rule from the US Environmental Protection Agency (EPA) regarding future power plants would affect only new coal plants.[4]

The EPA rule abandons the 'S' in CCS. No longer must the CO2 be sequestered from the atmosphere. Instead, the EPA carbon rule would be a protocol for how carbon capture must be used to increase supply of oil. EPA must rethink this rule before it is finalized.

The facade of the proposed EPA rule should not be surprising given the history of how carbon capture technology has developed. However, it will be disappointing if President Obama's environmental agency validates this expensive political distraction. Fortunately, EPA may be wavering when it comes to basing its proposed rule on the idea that scrubbing CO2 from new coal plants is a good investment.[5]

This report focuses on four reasons why EPA will be right to ditch support for carbon capture.

- Even data from the federal government, a proponent of CCS, shows CCS would be the costliest way to reduce CO2 pollution caused by electricity production.
- Increasing oil extraction is the real goal of developing CO2 capture. Capturing carbon means more, not less, climate pollution in the atmosphere.
- CO2 leakage is a worsening gamble. And people, not polluters, bear the risk.
- CCS threatens to make the overall environmental impact of using fossil fuels worse.

i Methane, 86 to 105 times more warming than CO2 as a greenhouse gas, is a greater problem in the short term. http://www.greenpeace.org/usa/en/campaigns/global-warming-and-energy/science/Natural-Gas-and-Global-Warming

"[Carbon capture] will eventually mature and become as common for new power plants as scrubbers have become for well-controlled plants today."
-Gina McCarthy, EPA Administrator[6]

1

CCS Is A Costly Distraction That Cannot Save The Climate

"CCS is the only proven set of technology that will allow us to cut carbon pollution while still using coal."
-Rep. Jan Schakowsky (D-IL)[7]

CCS is a tempting solution for decisionmakers who prioritize the next election over leadership. CCS allows politicians to call for action on climate in a way that doesn't upset their fossil fuel campaign donors. It is neither electric utilities nor coal producers who give life to the idea that CCS is a climate solution. A 2012 study found that "the discourse is not really about CCS but politics in the form of narratives on promises, alliances and emotions caused by political actions."[8] Few country's elected leaders have pushed CCS as much as in the US, the country responsible for the most climate pollution already in the atmosphere.[9] And they have been egged on by techno-optimistic, fossil fuel-friendly analysis coming from places like the International Energy Agency and Global CCS Institute.

"In fact, the president is trying to create a future for coal."
-Rep. Henry Waxman (D-CA)[10]

CCS as Climate Solution

CCS proponents claim that carbon capture-enabled coal plants would provide "the greatest reductions in future US electric sector CO2 emissions" and highlight the urgency with which CCS must be applied in order to achieve these benefits.[11] One report went so far as to assert that applying CCS to all coal plants would result in greater GHG reductions than implementing renewables across half the U.S. electric grid.[12]

The International Energy Agency (IEA) has described CCS as "a necessity for a world hooked on fossil fuel." IEA estimated that CCS could achieve as much as 20% of the cumulative CO2 reductions needed by 2050 to avoid the worst impacts of climate change,[13] although later lowered its estimate to 14%.[14]

The International Energy Agency (IEA) is right to increasingly focus on renewable energy over fossil fuels, a dynamic reinforced as solar and wind development soars and communities work energetically to divest from coal, oil and gas.[15]

"CCS as a magical technology that solves the carbon problem for coal plants is oversold."
–Jim Rogers, former CEO and Board chair of Duke Energy[24]

The IEA acknowledged that CCS would have a long way to go before providing much of a climate benefit.[16] Lessons learned from a series of failed CCS projects reveal numerous technical, economic, social and regulatory risks.[17] IEA's analysis assumed, wrongly, that the captured carbon would indeed be sequestered, rather than used to augment the supply of other fossil fuels.

In 2009, IEA published its first "technology roadmap" for developing CCS quickly enough to avoid the worst impacts of climate change. Also in pursuit of avoiding climate catastrophe, countries have since agreed in the United Nations climate negotiations to keep global temperature from rising above 2 degrees Celsius (3.6 degrees Fahrenheit).[18] Many countries, supported by climate scientists, believe the goal should be to keep warming below 1.5 degrees Celsius (2.5 degrees Fahrenheit).[19]

Guided by the 2 degree goal, IEA set a global benchmark that CCS should be successfully sequestering about 300 megatons per annum (mtpa) of CO2 with 100 commercial-scale projects by 2020.[20] In 2013 IEA dramatically reduced this benchmark, to only 30 projects sequestering 50 mpta, or less than 1/10th of 1% of global CO2 emissions. Projects in the pipeline for completion by 2020 will also fail to meet this reduced target.[21]

IEA explained in a footnote of its revised CCS roadmap report that "[t]he 2030 and 2050 goals are in line with the [2 degree scenario] deployment vision, and will require accelerated action from 2020 to be met."[22] In other words, the failure to develop CCS as quickly as they had hoped just means we must now do more over a shorter time period. This explanation is impractical from an economic perspective, and reflects denial about the climate change time line. Even if IEA's ambitious CCS roadmap succeeds, it will not be much help. 2020 is the latest year GHG emissions must peak, and we may surpass 2 degrees by 2036 with the current trend.[23]

A Federal Embrace

In 1997, the US Department of Energy (DOE) launched the Carbon Storage Program, which undertakes CCS research and development, infrastructure, and global partnerships.[25] Both the Bush (second) and Obama administrations have backed the FutureGen CCS project in Illinois, first in the form of a new hydrogen plant, then later as a revamped oil plant.


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"The new [EPA] proposal sets a separate standard for coal-based units and requires the use of carbon capture and storage (CCS) technology, which is neither adequately demonstrated nor economically feasible."
-Thomas Kuhn, President of the Edison Electric Institute.[29]

In 2010, the Obama White House commissioned a CCS "Task Force" of federal departments and agencies to devise recommendations for "bringing 5 to 10 commercial demonstration projects online by 2016."[26] That same year, the Task Force claimed that CCS faced "no insurmountable technological, legal, institutional, or other barriers that prevent CCS from playing a role in reducing GHG emissions." But from an economic standpoint, the Task Force concluded that to be deployed at a relevant scale, a price on carbon is necessary – a prospect which has fallen from the horizon.[27] By the time the Task Force released its recommendations, the US had nonetheless already invested more in carbon capture than any other national government, as below details.[28]

Following the Task Force Report, Senators Jeff Bingaman (D-NM), John Barrasso (R-WY), Jay Rockefeller (R-WV) and Lisa Murkowski (R-AK) introduced the "Department of Energy Carbon Capture and Sequestration Program Amendments Act of 2011." The bill aimed to "authorize the Secretary of Energy to carry out a program to demonstrate the commercial application of integrated systems for long-term geological storage of carbon dioxide" for up to 10 demonstration projects.[30]

The following year, Representative David McKinley (R-WV) introduced H.R. 6172 to "prohibit the Administrator of the Environmental Protection Agency from finalizing any rule imposing any standard of performance for carbon dioxide emissions from any existing or new source that is a fossil fuel-fired electric utility generating unit unless and until carbon capture and storage is found to be technologically and economically feasible."[31]

At first blush, it may seem like the Bingaman and McKinley initiatives were at odds, but in fact they were politically consistent. The coal extraction industry sees CCS as useful only insofar as it will delay EPA regulations on CO2. Operators of coal-fired power plants have little or no interest in carbon capture, and they are likely opposed unless public money covers the cost.

Legislation introduced in the previous Congress by Senator Rockefeller would have expanded tax incentives, loan guarantees, and other federal subsidies for CCS.[32] It was not due to lack of support that new incentives never came to a vote, but more likely because the 112th and 113th Congresses were the first and second most dysfunctional in history.[33] That Members of Congress are influenced by campaign donations from the oil industry was illustrated clearly in the January 2015 debate about the Keytone XL pipeline.[34] Members who voted for a bill approving the pipeline received 13 times more money from the oil and gas industry compared with legislators voting against the pipeline.[35]

Carbon capture projects already have access to substantial federal tax incentives thanks to bipartisan legislation passed in previous years. Power sector tax credits include a 20 percent investment tax credit for carbon capture coal projects using integrated gasification combined cycle technology (IGCC), or a 15 percent credit for non-IGCC projects. These credits were established in the National Energy Policy Act of 2005. In addition, the Emergency Economic Stabilization Act of 2008 created tax credits per ton of captured CO2. Capped at 75 million tons, CO2 captured and injected for geological storage receives a credit of $20 per ton, whereas CO2 used for increasing oil extraction receives a $10 per ton credit. President Obama's 2016 budget request would add another $2 billion in tax incentives for carbon capture projects.[36]

Currently, DOE runs a number of programs to support carbon capture. This includes the Regional Carbon Sequestration Partnerships, which covers the entire contiguous United States, comprised of seven regional partnerships that aim to research and develop storage sites for captured carbon to which it has allocated about $100 million per year.[38] The 2009 "American Recovery and Reinvestment Act" (ARRA) allocated significant ongoing funding to carbon capture, $3.4 billion annually, in order to develop and deploy carbon capture, primarily with the Clean Coal Power Initiative (CCPI). DOE also administers loan guarantees for carbon capture projects.[39]

"If our nation is to benefit from the next generation of clean coal technology, the private sector needs greater certainty and robust financial support in order to make the necessary investments."
-Senator Robert Byrd (D-WV)[37]

For the CCPI, DOE has issued three solicitations for projects. There remains only one project in the second round dedicated to CCS, and three in the third round. Under the loan guarantee program DOE has only ever approved two applications for projects that incorporated CCS, one of which would have used the CO2 to increase oil extraction but was abandoned.[40] DOE nonetheless is soliciting another $8 billion in loan guarantees for "clean fossil energy innovation."[41]

The loan guarantee program may not be as wasteful in theory as a federal grant, but it still constitutes a public subsidy in keeping with the World Trade Organization definition of a subsidy – a financial contribution by a government or any public body which confers a benefit to a specific industry.[42] In addition, a Governmental Accountability Office report found that half of federally guaranteed loans for energy projects go into default, in which case the US taxpayer foots the bill for any disbursement not recovered.[43]

With all the projects abandoned under the CCPI and loan guarantee program, cost concerns were the main issue cited. Thus, at the drafting of this report- there remain four utility-scale CCS projects as part of the CCPI, and every single one is intended to use the scrubbed CO2 to increase oil extraction.

There was one other carbon capture power plant project, FutureGen, which was a long saga begun under President Bush in 2003, and revamped multiple times. FutureGen was canceled in early 2015 for the third time. The FutureGen cancellation was again due to costs, as well as, reasonably, the likelihood it would not meet the deadline for completion.[44] Private backers of FutureGen are suing in Illinois court to get electricity ratepayers to cover their costs.[45]


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Utility-Scale Carbon Capture Projects in the United States

The prospect that any of the utility scale carbon capture projects in the United States survives to completion remains uncertain. However, a Canadian project began operation in 2014, the only other large-scale carbon capture project in North America. In many ways the Canadian project is similar to the four US projects on the table. Run by SaskPower in Saskatchewan, Boundary Dam started as a larger project. In the end it was a 110 megawatt coal (lignite) plant retrofit. The Canadian government provided $240 million in funding for a 300 megawatt plant, although Saskpower was able to keep the full subsidy. The provincial government is also providing financial support. Most of the CO2 scrubbed from smokestacks is used to increase oil extraction, which Saskpower is selling for about $25 million per year under a 10-year contract.[46] Boundary Dam is one tenth the size of the average new coal plant project, but it is hailed by CCS proponents globally as the first completed carbon capture project that is a power plant.[47]

Like Boundary Dam, all four US projects are receiving significant public funding – in one case more than the construction cost of the plant if guaranteed loans are included. The US projects are also significantly smaller than the average new coal plant. Cost overruns are typical, often scandalously high. While these projects all receive public subsidies to keep CO2 from entering the atmosphere, paradoxically all of them would sell the scrubbed CO2 to the oil extraction industry.

At the Kemper plant in Mississippi, Southern Company would earn $50 million to $100 million annually selling byproducts, mostly the captured CO2.[48]

paradoxically all of them would sell the scrubbed CO2 to the oil extraction industry.

Kemper County Energy Facility (Southern Company)

Location: Mississippi

Plant type: new, coal (lignite); pre-combustion CO2 capture

Electricity generation capacity: 582 megawatts

CO2 target capture rate: 65%

CO2 fate: oil extraction

Original cost: $2 billion

Current cost estimate: $6.1 billion

Public funding: $4.23 billion

DOE grant – $270 million

Federal tax credits – $133 million

Ratepayers – $2.88 billion

Securitized bonds – $1 billion approved by the Mississippi Public Service Commission

Status: Under construction, currently due for completion in first half of 2016. Project initiated in 2007 in Florida, but moved to Mississippi in 2008 due to cost concerns. Construction began in 2010 and completion has been delayed several times. The Mississippi Supreme Court ruled in February 2015 that some of the rate hikes must be refunded, further threatening the project's viability.[49]

Texas Clean Energy Project (Summit Power Group)

Location: Texas

Plant type: new, coal (sub-bituminous, Powder River Basin); pre-combustion CO2 capture

Electricity generation capacity: 400 megawatts

CO2 target capture rate: 90%

CO2 fate: oil extraction

Original cost: $1.7 billion

Current cost estimate: $2.5 billion

Public Funding: $2.787 billion

DOE grant – $450 million

Other federal grants and tax credits – $637 million

State tax incentives – $100 million

China Export-Import Bank – $1.6 billion (loans)[50]

Local government grant – $5 million[51]

Status: In planning stages, and estimated to be operational in 2019. Initiated in 2011. TCEP was supposed to be completed in 2014.[52]

Petra Nova (NRG Energy and JX Nippon Oil & Gas Exploration Corp.)

Location: Texas

Plant type: new, coal; post-combustion CO2 capture

Electricity generation capacity: 250 MW

CO2 target capture rate: 90%

CO2 fate: oil extraction

Estimated cost: $1 billion

Public funding: $417 million

DOE grant – $167 million[53]

State tax incentives – Legislation passed in 2009 provides tax breaks for the first three facilities capturing at least 70% of their CO2, in addition to a 30-year severance tax reduction for oil produced using anthropogenic CO2.

Japanese Bank for International Cooperation – $175 million (loan)[54]

Nippon Export and Investment Insurance – $75 million (loan guarantee)[55]

Status: Under construction, estimated to be completed in 2016. Initiated in 2009. The Petra Nova project would be an addition to an existing 2,697 MW coal and gas-fired power facility more than three decades old, the WA Parish Generating Station. The Petra Nova project has been described as taking "steps to clean up its operations."[56] In addition to the new 250 MW coal-fired unit, a 75 MW gas-fired unit will be built in order to run the carbon capture process (using approximately 45 MW). The effective capture rate for the complete 2,947 megawatt facility (excluding the new gas-fired unit) will not be 90%, but more like 8%.[57]

Hydrogen Energy California Project (SCS Energy)

Location: California

Plant type: new, petcoke/ coal (sub-bituminous Power River Basin); pre-combustion CO2 capture

Electricity Generation Capacity: 405 megawatts

CO2 target capture rate: 90%

CO2 fate: oil extraction

Original cost: $2.3 billion

Current cost estimate: $4.028 billion

Public funding: $875 million

DOE grant – $408 million

Federal tax credits – $437 million

State grants – $30 million

Status: In planning stages, and estimated to be operational in 2020. Initiated in 2013. Previous developers of the project, BP and Rio Tinto, had each provided $55 million of investment prior to acquisition in 2011 by SCS.[58]

The effective capture rate for the complete 2,947 megawatt facility (excluding the new gas-fired unit) will not be 90%, but more like 8%.

Retrofitting the existing power plant fleet is therefore nonviable from a financial standpoint.

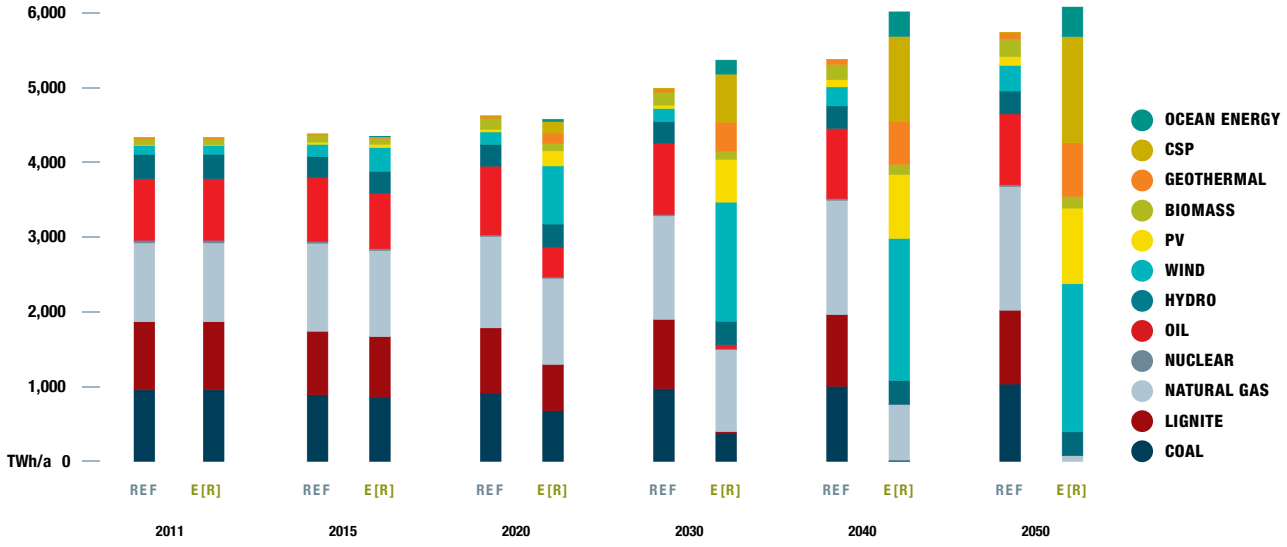
A Tragic Waste of Scarce Public Dollars

Billions of dollars of taxpayer money have already been spent on CCS under President Obama and his predecessors, but this is just a new type of fossil fuel subsidy. Oil and gas have received federal subsidies since 1916, about 60 years longer than renewables.[59] According to a 2011 study, cumulative federal subsidies over time for oil, gas, coal, and nuclear were $630 billion, versus $50 billion for renewables.[60] Despite significant public financing, CCS remains an exceedingly expensive and uneconomic investment for reducing climate pollution in the electricity sector.

Continued cost declines in the renewable sector, cheaper gas due to the rise of fracking, and public requirements on non-climate pollutants have driven down domestic coal demand. The utility industry and government project a continued decrease in coal use by the power sector.[61] Companies mining coal in the United States are therefore turning to international coal demand to stay in business. Fortunately, coal demand is not expected to rise for much longer in target markets like China.[62] In the immediate future, however, coal exports threaten to maintain or increase CO2 emissions from burning US coal, even as less coal is burned in the US. The industry and its allies nonetheless claim that coal exports would be good for the environment, but they are obviously grasping at straws.[63]

While politicians may claim that CCS is the future for coal demand, the truth is that coal has no future. The Greenpeace Energy [R]evolution scenario shows coal phased out in less than two decades, while we leave behind fracked gas as well (See Figure 1 comparing Greenpeace scenario to the gloomy forecast of the US Energy Information Administration).[64]

Figure 1: Electricity Generation Structure – Comparing Greenpeace E[R] Scenario with Energy Information Administration Scenario[65]



"[I]n Pennsylvania, that's a little less realistic for us unless we want to build a pipeline to Texas for our CO2, which I don't think is quite practical… [i]t's not something that could work in my neck of the woods."
-Rep. Mike Doyle (D-PA)[72]

Existing coal-fired power plants still remain the number one source of territorial US carbon pollution, and the new EPA carbon standard for existing power plants is imminent.[66] Policymakers have historically emphasized retrofitting power stations through the addition of post-combustion carbon capture technology. This option has proven too expensive to be feasible even with significant support from taxpayers and ratepayers.

Relative to what carbon capture projects have cost to date, most analyses of cost estimates are exceedingly generous. One collection of studies, for example, estimates the capital cost for post-combustion equipment at $1,604 per kilowatt of capacity[67], meaning a power station of only 500 MW would cost $800 million to retrofit. This figure does not include the costs of transportation and storage of CO2, nor does it account for the energy use of the capture system itself. The power consumption of capture and compression equipment may reduce the effective generating capacity of the 500 MW plant to 350 MW, since the energy penalty can be from 20–30%.

The US Department of Energy conducted a separate study and estimated capital costs of $1,319 per kilowatt to retrofit post-combustion capture, with a 31% loss in energy output as a result. [68] Capital costs of retrofitting using oxy-firing technology are also high, on the order of $1,044 to $1,060 per kilowatt with reductions of 33–36% of power output.[69]

Integrating CCS into new, pre-combustion capture stations is widely agreed to be the least expensive. Retrofitting the existing power plant fleet is therefore nonviable from a financial standpoint.

For a fiscally prudent CCS advocate, the fact that we currently use fossil fuels for electricity is irrelevant. The question they must answer is why new power plants with CCS are preferable to any other new energy investment, such as wind farms, solar arrays, or efficiency measures. But economics matter less when public funds are available. In addition, the oil industry may be increasingly willing to cover costs in order to obtain CO2 for use in increasing oil extraction.

Pipelines are the most likely method for moving captured CO2 to storage locations. In some cases CO2 could be transported by ships, rail or road transport. CO2 transport via pipeline can be a relatively low risk endeavor, but building new pipelines across public and private property will come with legal obstacles and costs. Attempting to meet climate targets with CCS in the United States would require up to 23,000 miles of additional CO2 pipelines between power plants and geological storage sites that could be a thousand miles away.[70] Operation and maintenance of this pipeline infrastructure could cost up to a $220 million per year,[71] an estimate which would be a small fraction of the cost of any utility-scale carbon capture project. However, most if not all new CO2 pipelines are being built to extraction sites rather than to sites intended for geological sequestration.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Tacking CCS onto a traditional coal plant is estimated to increase the plant's operating costs by about 75% according to the Congressional Budget Office (CBO). CBO thus concluded in 2012 that CCS could not take off in the utility industry without the backing of some federal restriction on carbon emissions.73 This conclusion does not differ greatly from that of the Obama administration's Interagency Task Force on Carbon Capture and Storage.[74]

Of the six projects to receive funding under round three of the Department of Energy (DOE) Clean Coal Power Initiative, three withdrew as of April 2012. In each case, it was revealed that cost concerns played a role in the withdrawal. Large-scale CCS demonstration projects have access to about $21.4 billion in funding across the globe.[75] Currently, more unallocated public funding is available to the US power sector than in any other country.[76]

Given the opportunity cost of energy investments, proponents of CCS must show how it is cost effective compared with other ways to reduce the climate footprint of electricity production. But this is an impossibility. There is no escaping that CCS is more expensive per kilowatt hour than investing in new power generation from renewables. Based on a 2013 study, taking into account life cycle CO2 emissions of each source and cost of new investment, CCS for coal is 124 times less cost effective than wind energy per gram of avoided CO2 pollution. This exorbitant difference includes only the price of electricity infrastructure and only climate pollution. It does not account for any of the widespread public health costs of using coal.[77]

While the US Energy Information Administration, part of DOE, has been sympathetic to CCS in its analysis, its own cost projections for new energy sources show that CCS is the most expensive method of avoiding additional CO2 emissions.[78] In Figure 2 we compare the cost of avoiding a kilogram of CO2 emissions per unit of electricity (kilowatt hour). See Appendix I for an explanation of the methodology. This chart uses referenced data that is very sympathetic to CCS, even beyond EIA cost figures. It assumes a 90% capture rate and that bituminous coal is burned, which has the lowest CO2 emissions per unit of energy.[79] It assumes very low life cycle GHG emissions from coal.[80] It assumes the the most efficient new coal plants (IGCC).

However, we know that coal plants are often using lower quality lignite or sub-bituminous coal, may have lower capture rates (65% for Kemper), cost far more in part because they are retrofits, and aren't even intending to sequester the CO2. So, Figure 2 is overly fair to CCS. Nonetheless, it shows CCS would cost almost 40% more per kilogram of avoided CO2 than solar PV, 125% more than wind, and 260% more than geothermal.

Figure 2: Cost of Avoided Emissions per EIA (kilograms per kilowatt hour)

Type of Utility-scale Energy Facility	conventional coal (bituminous)	coal with carbon capture (IGCC, 90% capture)	Solar (PV)	Wind	Geothermal
System-wide cost per kwh (a)	$0.10	$0.15	$0.13	$0.08	$0.05
Point source CO2 emissions (b)	0.938	0.0938	0	0	0
Additional life cycle GHGs (mining, production, transportation, etc.) (c and d)	0.077	0.077	0.0039	0.0051	0.0386
Emissions from carbon capture energy penalty (20% more coal input)	0	0.01876	0	0	0
Total emissions	1.015	0.18956	0.0039	0.0051	0.0386
Grams of avoided emissions	0	0.82544	1.0111	1.0099	0.9764
cost per kilogram of avoided emissions	**n/a**	**$0.18**	**$0.13**	**$0.08**	**$0.05**

Sources

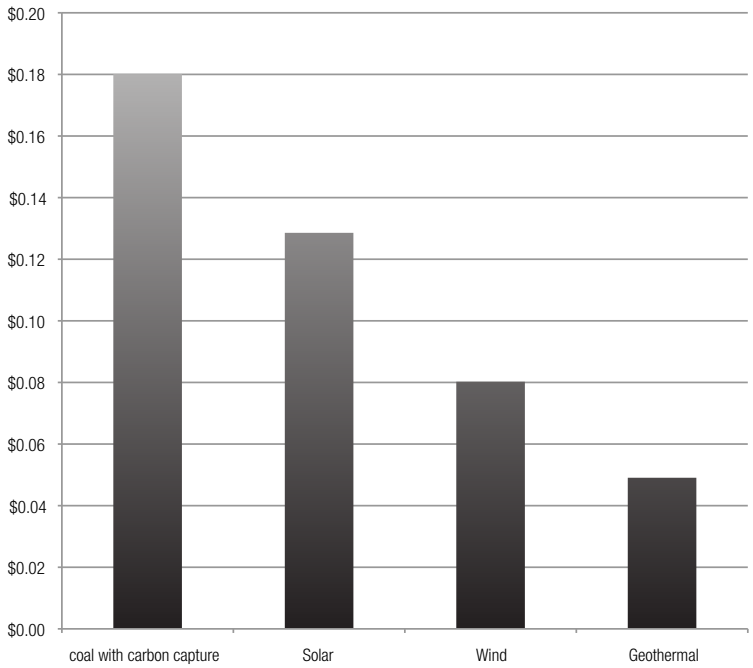
a) EIA. "Annual Energy Outlook." 7 May 2014. Accessed 16 March 2015. http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

b) EIA. Accessed 16 March 2015. http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11

c) life cycle emissions additional for coal and NG derived from Jaramillo, et al. "Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation." Environmental Science and Technology. 17(41). 2007. Accessed 16 March 2015. http://www.cmu.edu/gdi/docs/environ.-sci.-technol-2007-jaramillo.pdf

d) life cycle emissions from renewables derived form Sovacool, et al. "Comment on 'Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nucelar Power," Environmental Science and Technology. 47(12). 22 May 2013. Accessed 6 March. 2015. http://pubs.acs.org/doi/abs/10.1021/es401667h

Figure 3: Relative Costs of Avoided CO2 (per kilogram, per kWh)



2

Capturing Carbon Will Increase Climate Pollution

they must assume that a critical majority of the injected CO2 eventually stays underground. Unfortunately, this assumption fails.

Australia, the second largest exporter of coal after Indonesia, announced in 2009 a new initiative called the Global CCS Institute to promote CCS development world-wide.[82] The Institute says the business case for carbon capture rests on the 'twin pillars' of public support and market opportunity.[83] The exorbitant cost of CCS and political difficulty in generating taxpayer support has made proponents turn more and more to market opportunity, at the expense of theoretical integrity in the argument that CCS could help the climate.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CC-EOR Is an Oil Industry Strategy

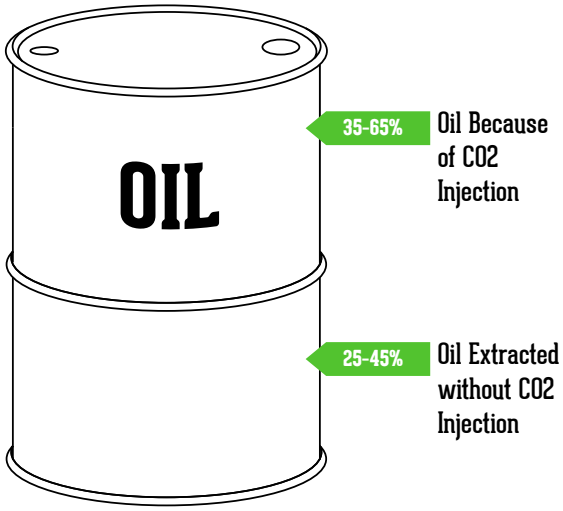
CCS proponents do not bother to hide that the major selling point behind carbon capture is its role in 'enhanced oil recovery' (EOR) – which is *not* a better method of cleaning up spilled oil, as one might guess the term means. They aren't recovering oil, since they never had it in the first place. And 'enhanced' doesn't mean any improvement in quality. In fact, the oil is more highly saturated with CO2, so it's worse for the climate. EOR is a euphemism for increasing oil extraction.

Responsible for 6% of U.S. oil production today, up from virtually nothing in the 1980s, industry claims to have been using CO2-EOR for more than three decades. CO2-EOR works by pumping CO2 underground to force out oil that otherwise could not be extracted.[84] Some claim that without CO2 injection 65% of the oil would be left underground.[85] In other words, under the auspices of helping the climate, carbon capture will be used to increase oil extraction by as much as 185%.

"The advancement of CCS technologies is essential if new coal power plants are to operate in the low carbon future we must achieve."
-Rep. Suzanne Bonamici (D-OR)[98]

Currently, CO2-EOR operations rely mostly on CO2 extracted directly from natural CO2 reservoirs, usually in close proximity to oil rigs. Natural CO2 supplies are exhaustible and really only available in the United States, although the rising demand for anthropogenic CO2 to increase oil extraction is global.[86] In the Permian Basin demand for CO2 by the oil industry began to exceed supply in 2004.[87]

Figure 4: CO2 Injection = Much More Oil[88]



The majority of CO2-EOR operations are in Permian Basin (Texas and New Mexico), where high-quality CO2 sources reside near oil reservoirs "amenable" to EOR.[89] One analysis called EOR "the main driver behind CCS," which was before federal regulations on GHG emissions.[90] Oil companies, such as BP, view CO2-EOR as the only way to maintain or increase production.[91] Another analyst rightly noted, "...not only does CCS need CO2-EOR to help provide economic viability for CCS, but CO2-EOR also needs CCS in order to ensure adequate carbon dioxide supplies to facilitate growth in production from EOR."[92] In 2010 there were already 129 CO2-EOR projects – only one was labeled as a CCS project.[93]

The oil industry has viewed carbon capture with EOR (CC-EOR) as a key part of their expansion before any public relations work to greenwash it.

No Green Stamp

The logical foundation of proponents of CC-EOR is presented in a 2012 report commissioned by the National Enhanced Oil Recovery Initiative (NEORI). The report states "[i]n a fortunate, if ironic, twist of fate, a key to increasing America's domestic energy security lies in capturing and productively utilizing a portion of our nation's industrial CO2 emissions, thereby meeting a critical domestic energy challenge, while also helping to solve a global environmental problem."

NEORI describes itself as a diverse set of constituents. While three of NEORI's 35 members and observers are environmental NGOs, the overwhelming majority have a stake in carbon capture or EOR whether or not there is a climate benefit.[94] They are surely quite happy to call it 'green tech.' NEORI has succeeded in getting their recommendations into legislative proposals, such as tax credits proposed by Senator Jay Rockefeller (D-WV).[95]

Since 95% of oil is extracted to be burned, thus creating more CO2 pollution, there is no simple logic that using CO2 to increase oil supply benefits the climate.[96] CC-EOR proponents making a case for the climate therefore must rely on a set of elaborate political economic assumptions.

Even if they admit that there is some reduction in the climate benefit, **they must assume that a critical majority of the injected CO2 eventually stays underground.** Unfortunately, this assumption fails. One reaason is that extraction companies do not re-capture the CO2 during production. An analysis of existing CO2-EOR operations noted that "accounting for CO2 losses is not typically done for EOR."[97] That is not surprising because for oil companies sequestration of CO2 is not an objective – growth of their industry is.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There is no reason to believe industry practices are geared toward anything but maximizing oil sales. Creating an incentive for CC-EOR-with-Storage would require heavy carbon taxation, according to the IEA.[99] There is no such policy in the US, and it doesn't appear the Republican-controlled Congress is anywhere near considering a carbon tax.

There are few peer-reviewed studies of lifecycle greenhouse gas emissions from CO2-EOR projects. However, one study of five projects revealed that – between mining coal capturing carbon from the coal plant, utilizing the carbon for EOR, and burning the produced oil – CC-EOR can result in a net *increase* in carbon emissions.[100]

Achieving a net reduction in emissions would require making sure that most of the injected CO2 does not escape with extracted oil, or at least that it is 'recycled' (neither of which the proposed EPA carbon rule on new coal plants would require). Even then, the practice would have to be industry-wide. If one company were obligated to capture the CO2 which returns to the surface with extracted oil, the injected CO2 does not stay confined to one drilling rig's operations. As intended, injected CO2 becomes mixed and dispersed with the oil underground, which means it can be extracted by other companies' drill rigs as well. Thus, 'recycling' a critical majority of injected CO2 may not even be physically possible in many cases. There is also the problem of abandoned wells, which the next chapter will discuss.

The second false assumption is that CC-EOR makes strategic sense for scaling up investment in CCS in general. The Global CCS Institute, NEORI, and others claim that this shrewdly harnesses oil industry profit incentive in order to augment overall investment in CCS. This view may be theoretically sound with respect to capital investment in general, and perhaps with achieving economies of scale at some point far into the future (too far to matter for mitigating climate change). But it cannot be true when it comes to building fixed infrastructure. It would not be economical, nor practical, to take ***a)*** custom built infrastructure designed to scrub CO2 from a new lignite-fired power plant in Mississippi to pipe to an oil extraction site less than 100 miles away (i.e., Kemper plant) and then export it to ***b)*** retrofit a non-lignite coal plant in China in order to sequester the CO2.

The NEORI optimism about harnessing private oil investment appears to view oil money as finite and public dollars as limitless – but they have it backwards. Taxpayer dollars are scarce, whereas the 2014 revenue of the top 15 oil companies was about $4 trillion,[101] more than the entire US federal budget. DOE claims to be subsidizing CC-EOR with the aim to encourage CCS at a scale that would benefit the climate, which means it is ignoring its own analysis. A DOE-commissioned study concluded that "[CC-EOR] is unlikely to serve as a major stepping stone to commercial-scale CCS deployment."[102]


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Oil companies have turned to EOR to be able to sell more oil, after exhausting more easily obtainable supplies.

The third and most dubious assumption is that oil companies choose not to develop new wells if they can get more out of existing wells. However, one might attempt to make this 'zero sum production' claim more rigorous. Analyst Jaramillo says "[t]he key argument for CO2-EOR as a sequestration method is that the electricity and oil produced within the system boundary displaces oil or electricity from other sources." For example, assume BP producing oil in the Gulf means Suncor produces less carbon-intensive tar sands oil in Alberta. This economic rationalization made by those with apparent misgivings about supporting CC-EOR is obviously a non sequitur.

Regarding Jaramillo's point about sources of electricity within the system boundary, investing in CC-EOR arguably displaces investments in renewables if it extends the life of a coal plant or results in new coal-fired capacity that wind or solar could otherwise provide.

The aforementioned DOE study found CC-EOR contributes little if anything to CCS deployment in part because CC-EOR momentum exists to make the oil industry more profitable. It is clear that for the industry this is about extracting more oil – growing more as an industry – than they otherwise could. The oil industry's plans for profit growth are not just amoral but myopically oriented toward selling as much oil as possible.

Exxon CEO, Lee Raymond, famously declared that the company was not American and did not make decisions based on what's good for America, but he might as well have said that companies whose aim is making money from oil supply do not make decisions based on what's good for the global economy or even themselves.[103] Climate disruption will impact all of us.

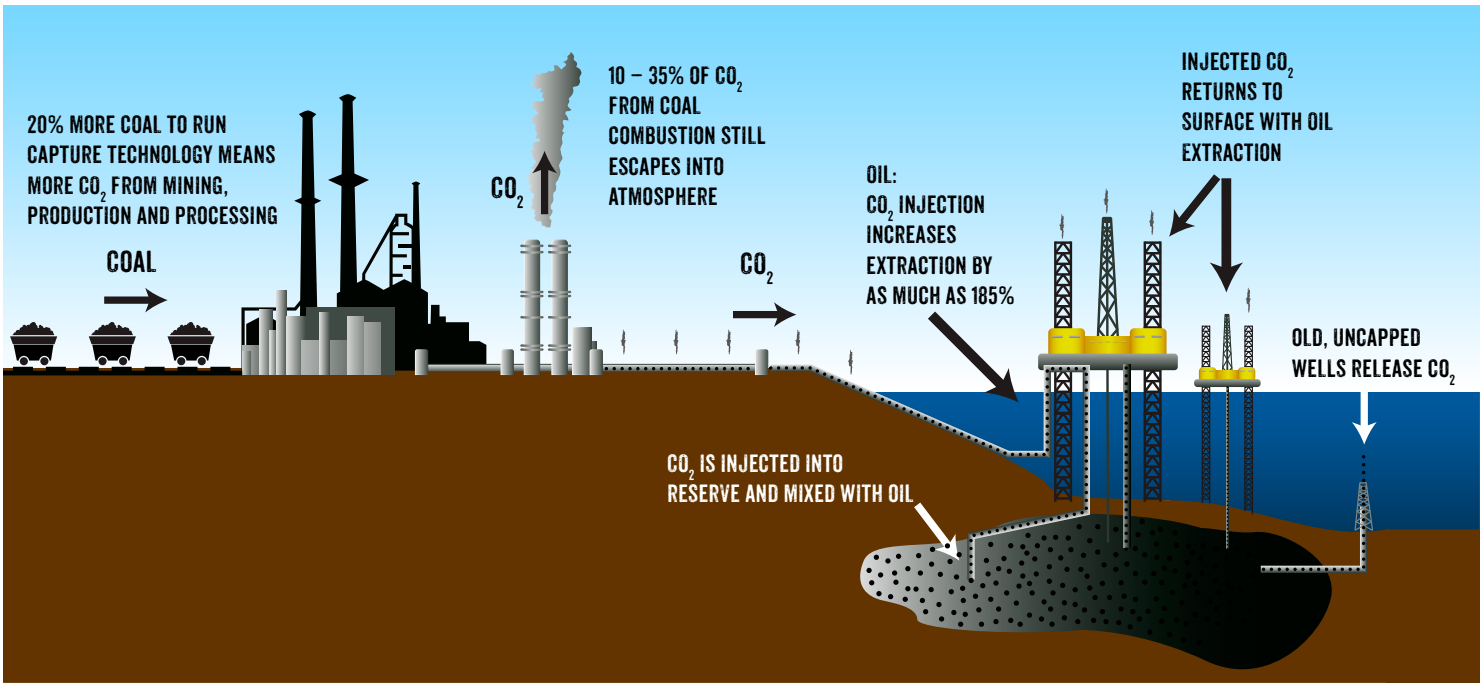
CC-EOR is no more a climate solution than drilling in ultra-deepwater, hydro-fracking, or drilling in the Arctic Ocean. These are just next steps for an industry destroying the climate. Oil companies have turned to EOR to be able to sell more oil, after exhausting more easily obtainable supplies. There is no escaping that, as Jaramillo states, "without displacement of a carbon intensive energy source, CO2-EOR systems will result in net carbon emissions."[104]

Oil produced from injection of CO2 captured from coal plants is arguably is worse than conventional oil, since it is part of scheme to either build new coal plants or keep existing plants from shuttering. Emissions from CC-EOR will include emissions from coal extraction, processing, new coal combustion (not all the CO2 is captured), not to mention combustion of oil that would otherwise stay in the ground.

World-wide, all but three of the thirteen large-scale, carbon-capture projects to have begun operating use the captured CO2 for EOR operations. None of the three non-EOR operations is a power plant. They are gas extraction operations designed to re-inject underground the CO2 scrubbed from raw natural gas. One of the three operations, in Algeria, was suspended indefinitely in 2011. The other two are both operated by Statoil in Norway. Statoil avoids paying tens of millions of dollars per year under Norway's carbon tax system.[105]

The Global CCS Institute is of course optimistic that EOR "is promoting early deployment of CCS."[106] However, even if one gives undue acknowledgement to the other 40 carbon capture projects which the Global CCS Institute documents on paper could operate in the next decade, only 9 aim to sequester CO2 captured from a power plant.[107] FutureGen would have been a 10th and was for quite a while the most likely to succeed. FutureGen was the last remaining large-scale carbon capture power plant project in the US that aimed to sequester its CO2 pollution.

Figure 5: CO2 Capture = More Coal, More Oil, More CO2



3

Sequestration is a Bad Bet; People – not Polluters – Bear the Risk

Once a CO2 molecule is emitted into the air, it can take two centuries before it is reintegrated into natural carbon sinks like forests. This report uses the terms 'storage' and 'sequestration' interchangeably because that is the norm, although it may be more appropriate to say that storage implies 'artificial sequestration' or the attempt by humans to sequester CO2 at a scale and rate not possible naturally.

Odds of CO2 Leakage are High, and Leakage is Bad

In order for CCS to deliver a lasting benefit to the climate, the vast majority of sequestered CO2 must remain underground permanently. Geological formations proposed are sub-seabed and saline aquifers. The IEA says that depleted oil and gas reservoirs would be the most likely candidates for initial storage operations because of both their geology and proximity to industrial development.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The problem with IEA's assertion is it is too convenient for expanding CO2-EOR operations. In addition, the multiple bore holes and wells drilled in them to find and extract oil and gas further increase the risk of leakage. The IEA also admits that, "[t]he long-term storage integrity of oil fields that have been exploited with multiple wells has yet to receive serious scientific investigation."[108]

The prominent Sleipner project, a CCS storage testing site off the coast of Norway injecting CO2 scrubbed from raw gas after extraction, was found in 2012 to have many nearby fractures, warranting increased expense toward surveying the geology of such sites.[109] Some scientists say it's not a matter of if the site will leak, it's just a question of when.[110] Researchers devoted to the promise of CCS remain unconcerned.[111]

However, undue confidence in understanding of the geology at Sleipner is not new.[112] While offshore injection may be easier for the public to accept, deepsea sites will be more difficult to monitor. There are few studies to ascertain potential effects of undersea CO2 leakage, but scientists have concluded that it may be detrimental across the ocean food web.[113] CO2 leakage from sequestration could exacerbate already rising ocean acidification, since the ocean absorbs about 25% of anthropogenic CO2 pollution. This is threatening a different type of planetary disaster altogether.[114]


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With regard to injection into deep-saline aquifers, a recent MIT study seriously undermines previously held assumptions about the chemistry of CO2 integration with geology underground. This study indicates that the majority of injected CO2 could uncontrollably make its way back to the surface.[115] In addition, researchers at Stanford University argued that CO2 injection carries a "high probability" of instigating earthquakes that can "threaten the seal integrity" of the storage site.[116] The $2.7 billion In Salah project in Algeria was suspended indefinitely in 2011 after CO2 injection led to microseismic events that fractured the caprock. This occurred after injecting only 3.8 megatons of CO2 (less than a year of emissions from one average-sized new coal plant).[117]

Just like the two projects in Norway, the In Salah project was attempting to sequester CO2 scrubbed from raw natural gas, which is typically vented at gas extraction sites.


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Thanks to fracking for shale gas, we now also know that seismic activity is exacerbated by injecting the wastewater underground. Fracking is likely the reason why Oklahoma, an area not historically prone to seismic activity, has become the most earthquake-prone state on the continent.[118] In Oklahoma, like in other states where fracking is rampant, burning coal is still the primary source of electricity. Figure 6 and 7 show how fracking and CCS could be mutually exclusive in terms of geography.

The risk of CO2 leakage is also due to the reputation of the petroleum industry that does not clean up after itself. Many wells in oil and gas fields are improperly sealed or not sealed at all. For example, an investigation conducted by the Associated Press (AP) in the wake of the BP Deepwater Horizon disaster found that oil companies "routinely circumvented" regulations for temporarily abandoned wells. More than 1,000 temporarily abandoned wells in Gulf of Mexico "lingered in an unfinished condition for more than a decade."[119] In that same AP investigation, while an oil company representative insisted that it was in everyone's interest to seal wells and to do so properly, state officials estimated that "tens of thousands [were] badly sealed, either because they predate[d] strict regulation or because the operating companies violated the rules."[120]

In March 2013 a Texas company, Denbury Resources, was fined for a blowout that occurred during a CO2-EOR operation in Mississippi. So-called 'downhole communication' (called 'frack hits,' if resulting from fracking operations) occurs when underground injection connects with old wells, proving an escape route for the injected CO2 to come back up to the surface uncontrollably. In the Denbury EOR operation so much CO2 came back up old, poorly-capped wells that local wildlife died from asphyxiation. More than 12 million oil and gas wells have been drilled in the United States. More than 3 million of wells have been abandoned, many of which may never have been capped at all. Incidentally, Denbury Resources intends to purchase the CO2 that would be captured by the Kemper project for oil extraction in the Gulf region.[121]

Figure 6: Potential Sites for CO2 Sequestration[122]

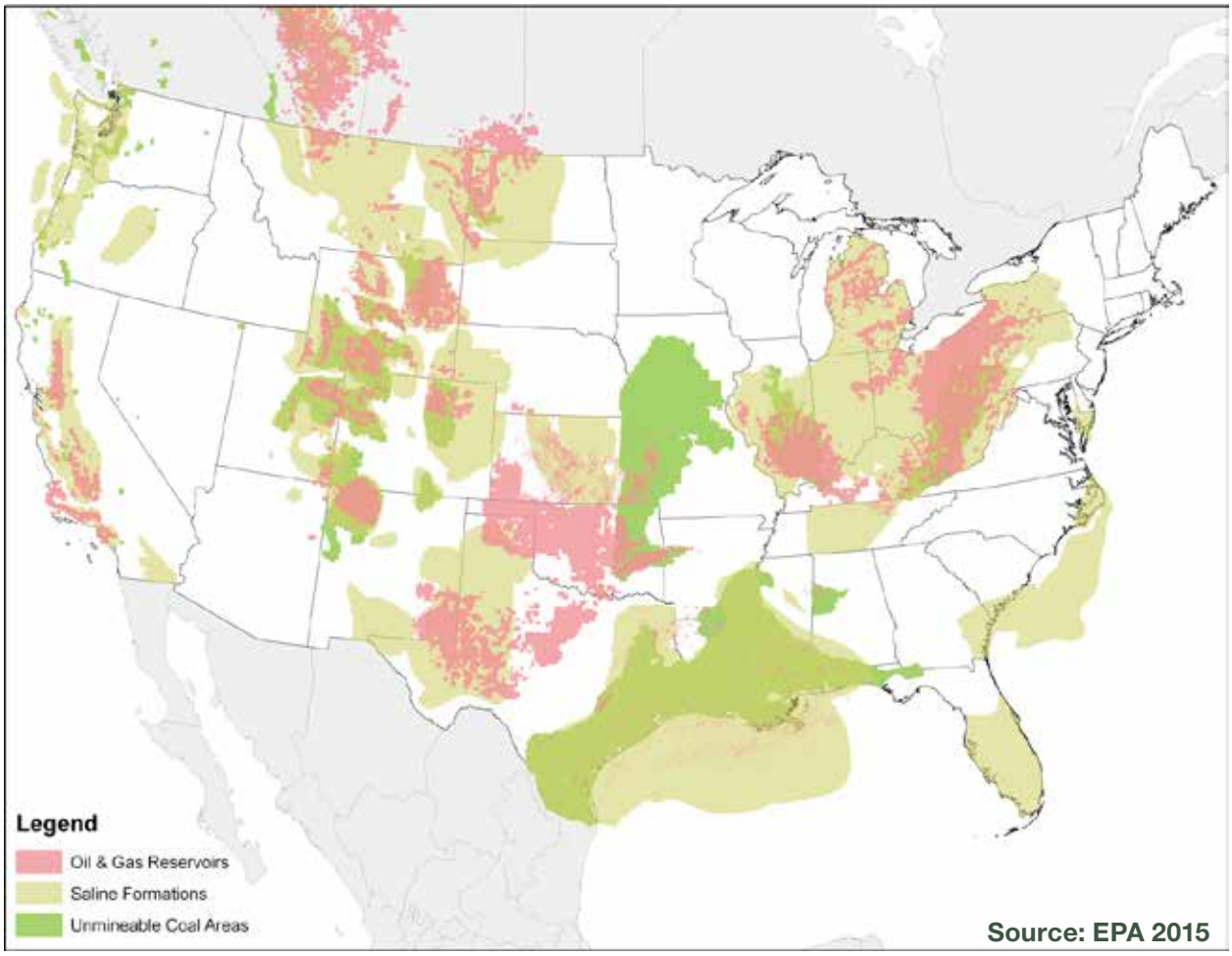
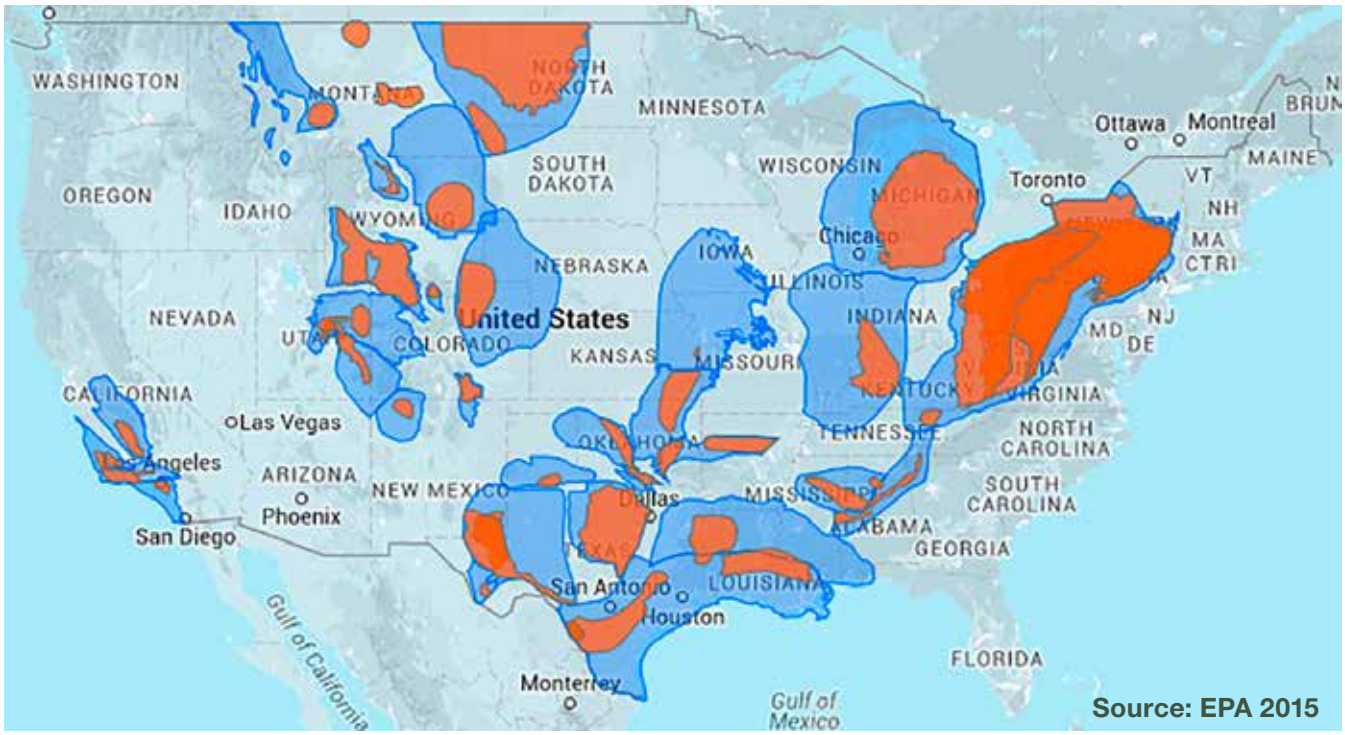


Figure 7: Areas of Active or Potential Fracking[123]



"Charting a path toward clean coal is essential to achieving my Administration's goals of providing clean energy, supporting American jobs, and reducing emissions of carbon pollution."
-President Barack Obama[128]

Fossil Fuel Industry Doesn't Mind the Odds

The fossil fuel industry has been actively advocating to shift responsibility and liability for CO2 sequestration and monitoring to the public, as they have also done for virtually any type of liability for their public health impacts. The oil and gas extraction industry is exempt from regulations under possibly every federal environmental law, including the Safe Drinking Water Act, Clean Air Act, Clean Water Act, and Superfund law.[124] In 2013, EPA decided that CO2 captured for geological sequestration would be exempt from hazardous waste regulations under the Resource Conservation and Recovery Act, although pointing out industry was already exempt if the CO2 is used to increase oil extraction.[125]

Industry also succeeded at transferring liability with respect to international CCS policy. In the 2011 Durban international climate negotiations, countries agreed to allow CCS projects to be eligible for application to the Clean Development Mechanism (CDM). Under the agreement, industry will be required to monitor sequestration sites for only twenty years after credits for sequestration have ceased, even if injection is still occurring, after which liability for any leakage is transferred to the host country (to the public).[126] Japan, the UK and Norway have counted investments in carbon capture in developing countries toward their climate finance obligations agreed during the UN climate negotiations, including grants by Norway for CO2-EOR research in India.[127]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4

CO2 Capture Will Increase the Environmental Impact of Coal

Carbon capture would do nothing to reduce mercury pollution, and could even exacerbate it by producing greater amounts of coal ash.

Let's assume CCS could work as its most idealistic proponents might argue. Assume it isn't being developed for increasing oil extraction, but instead to sequester the CO2 permanently from the atmosphere. At best, CCS would mitigate some of the carbon pollution associated with burning coal, but it would do nothing to address a long list of many other environmental and public health harms associated with coal use in the power sector. CCS would exacerbate many of these harms not just because it would support continued use of coal, but because power plants using carbon capture require 20% or more coal to provide the same amount of electricity.

Using coal for electricity requires mining, washing and processing, transporting, burning, as well as disposing of ash – in stark contrast with relying on the wind and sun for energy. This last section highlights some of the key ways in which CCS would magnify coal's environmental footprint.

Water Use

Coal-fired power plants are the largest users of freshwater (more than agricultural withdrawal) in the United States,[129] a particular problem for Western and Midwestern states stricken by longer and more extreme droughts caused by climate change.[130] According to the US Department of Energy (DOE), both coal and natural gas-fired power plants with carbon capture would consume far more water, up to twice as much as non-carbon capture plants.[131] Coal plants also release and incredible amount of heated wastewater, damaging local freshwater ecosystems.

Air and Water Pollution

Coal combustion remains a major source of many air pollutants, including sulfur dioxide that causes acid rain and particulate matter that causes health impacts such as asthma.[132] Coal combustion has historically been the number one cause of mercury contamination in US waterways.[133] Half of the navigable lakes and rivers in the United States are closed to fishing and swimming at any given time, the majority because of mercury contamination.[134] New mercury pollution standards will help, but a


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significant amount of mercury pollution drifts into the United States from coal combustion in other countries such as China.[135] Carbon capture would do nothing to reduce mercury pollution, and could even exacerbate it by producing greater amounts of coal ash.

In addition, drinking water is contaminated by every part of the coal waste stream with chemicals and compounds that cause cancer, birth deformities, and other health issues.[136] This is because the coal industry's contribution to pollution in our rivers, lakes, and seas includes a laundry list of toxic chemicals and compounds, such as cyanide, arsenic, selenium, ammonia, sulfur, sulfate, nitrates, nitric acid, tars, oils, fluorides, chlorides, and other acids and metals, including sodium, iron, thallium, cadmium, beryllium, barium, antimony, and lead.[137]

Toxic Coal Ash

Coal plants using carbon capture will produce more coal ash because the technology requires power to operate – 20 to 30% of the coal ash generated per kilowatt hour would be related to carbon capture.[138] After mining waste, coal ash is the largest waste stream in the country, as it is in other countries like China.[139]

Coal ash is laden with other cancer-causing chemicals and heavy metals, and most coal ash produced in recent decades sits in unlined 'ponds' that continuously leach into groundwater.[140] Coal ash containment is so negligent that massive quantities have spilled on multiple occasions, contaminating rivers and even wiping out nearby communities.[141] In one infamous case in 2008, 1.1 billion gallons of coal ash slurry (more than oil spilled from the Exxon Valdez) spilled from its containment near the TVA Kingston Fossil Plant in Tennessee, forcing evacuations from the town.[142] While new regulations on non-climate air pollutants will lead to cleaner air, it also means coal ash will become more toxic.[143]

In the United States, coal ash has never been regulated federally even though the problem crosses state boundaries, and most states have poor or no regulations on coal ash.[144] The TVA Kingston disaster prompted EPA to consider regulations in 2009, but decided six years later to provide a coal ash guidance in lieu of enforceable standards.[145]

Public Health and the Economy

Coal has a giant, negative impact on the economy. For instance, coal transport has traditionally dominated US rail capacity. In the United States, transporting coal has been responsible for a quarter of the carloads and half of the tonnage carried by train, although this has fallen in recent years with declining coal demand.[146] Coal trains can spill toxic dust along their path, can catch fire spontaneously, and generally get in the way of using railways for public transportation and transporting other commodities.[147] Industry plans to build new export terminals in the Pacific Northwest, threatening to increase its already massive footprint on transportation infrastructure.[148]

Adding up the monetized life cycle costs of coal used for electricity, such as health costs from its pollution and environmental cleanup, comes to as much as $523 billion per year in the United States on top of the price of electricity – $308 billion if climate-related costs are excluded. A 2010 Harvard study assessed the costs of coal pollution that result from lost work hours and lowered productivity due to various health conditions, including mental retardation (from mercury), cancer, cardiovascular disease, black lung and other pulmonary diseases, transport fatalities, asthma, and early death. While the study admitted the true ecological and health costs are worse, it concluded that "[a]ccounting for the many external costs over the life cycle for coal-derived electricity conservatively doubles to triples the price of coal per kWh of electricity generated."[149]

5

Conclusion

Even if we could manage to systematically inject some quantity of CO2 into the ground for a critical majority of power plants world-wide, it would greatly exacerbate other extremely destructive impacts of mining, processing, transporting, and burning coal.

This report has shown how even the most ambitious plans for CCS would not help avert the worst impacts of climate change. The IEA CCS roadmap will one day live in infamy as it continues to support the diversion of money and political will from real climate solutions, such as the development of renewable energy. So too will the EPA rule for new power plants unless the agency revises the rule to drop any validation that CCS is a good investment.

The Obama administration seems partly driven by faith in a technology that was supposed to sequester pollution from the atmosphere. The bigger reason, perhaps, is reflected in the mindset communicated by agencies across the administration, whether it comes to the KXL tar sands pipeline, selling taxpayer-owned coal and oil, or drilling in the Arctic.

Some CCS supporters claim that oil produced with CO2 injection is going to get produced somewhere else anyway, and therefore would actually be 'green' oil because it keeps CO2 from a coal plant from entering the atmosphere. Is this "clean coal" for "green oil"? This sounds confusing because it makes no sense – for the obvious reason that injected CO2 comes back up the well with the oil.

The Obama administration view appears to be that fossil fuel projects never contribute to climate change. Every federal agency has an excuse for why its okay to support new coal, oil and gas supply projects. For example:

- The US State Department analysis concluded the KXL pipeline won't contribute additional carbon pollution – because it means other oil transport methods won't be used.[150]
- The Bureau of Land Management auctions off taxpayer-owned coal and discounts any CO2 created by burning that coal – because it means coal in some other part of the world won't get mined. BLM says the same regarding gas extraction projects on public land.[151]
- The Bureau of Ocean Energy Management zeros out CO2 from burning oil extracted in the Arctic – because this means Arctic oil will simply displace oil on the international market.[152]
- EPA's proposed carbon rule reflects this logic too, by promoting oil production with CO2 injection without accounting for any of the CO2 injected, nor created by burning the oil later.

We hope EPA will rethink its proposed rule and come up with a final policy that acknowledges fossil fuel-fired power plants, not to mention fossil fuel extraction, are not the future of energy investment. Solar and wind are, as the Greenpeace Energy [R] evolution analysis has predicted more accurately than most.[153]

Human-caused global climate disruption is certainly a politically difficult problem. Many politicians, namely climate deniers, have simply chosen to look away or became willful allies of big climate polluters. However, many of the rest of our elected decision-makers desperately search for a climate solution that will alienate as few of their powerful fossil fuel constituents as possible. Unfortunately, there is no viable solution for both supporting the use of fossil fuels and the climate simultaneously. True climate leaders have no option but to tackle the damaging economic entrenchment of the coal, oil and gas industry. Climate leadership means opposing carbon capture and storage. Real climate solutions like building renewables, developing a smarter electric grid, energy efficiency, and reforestation are already working, but we need our decisionmakers to help pick up the pace.

Appendix

Methodology for Calculating 'Cost of Avoided Emissions per EIA' (kilograms per kilowatt hour)

The basis of the calculations is EIA projections for costs of new energy sources entering service in 2019. This short term projection makes it an estimate of new sources proposed today, since electricity generating units (EGUs) can take a few years from proposal to coming on line. EIA data is using 2012 dollars and megawatt hours (MWh). We used EIA data that excluded subsidies for system-wide, levelized cost. Therefore, this cost should include all variable and fixed costs, including fuel inputs and management of outputs like pollution abatement. It includes maintenance costs and should include the total cost of necessary infrastructure. This also accounts for capacity factor of each energy source, which is the average percentage of time the energy source is generating at full potential. For example, a coal plant is assumed to be at full production potential 85% of the time. On-shore wind capacity factor is 35% and Solar-PV is 25%. We converted EIA projections for system-wide, levelized costs into cents per kilowatt hour (kWh).

We used EIA data also for point-source CO2 emissions factors for various energy sources per kWh. This is the CO2 created by combustion of the fuel based on average heat rate of each fuel. EIA data is in pounds per kwh, which we converted into kilograms per kwh. We assumed bituminous coal is used. On average, bituminous coal has about 4.6% fewer emissions than lignite (brown coal) and 3.7% fewer emissions than sub-bituminous coal.

For upstream emissions of coal, such as emissions due to mining and transportation, we used analysis from Jaramillo, et al. This analysis was assessing comparative life-cycle emissions of coal with various types of domestic methane gas used in electricity production. They relied on a 100-year time horizon for methane, which is a significant component of upstream coal emissions related to mining. Given that avoiding catastrophic climate change requires drastic climate pollution reductions within the next two decades, it is better to use the 20-year time horizon in which case methane is at least three times as potent a greenhouse gas. Therefore, for this reason alone, we consider this life cycle emissions estimate to be very generous in favor of coal.

For the life cycle CO2 emissions of solar, wind and geothermal, we relied on analysis provided by Sovacool, et al. CO2 emissions associated with solar, wind and geothermal are largely due to production of infrastructure and components.

To calculate the cost per kilogram of avoided CO2, we first had to choose a baseline for emissions to be avoided from new energy sources. For this baseline we referenced the emissions from a coal plant without carbon capture that is burning bituminous coal.

To calculate total emissions of each energy source, we added together all the point source emissions with additional life cycle GHGs, as well as the emissions associated with additional coal needed to operate carbon capture (i.e., the energy penalty of CCS). This energy penalty for CCS we assumed is 20%, although it could be as high as 40%. We also assumed the coal plant with CO2 capture is the most modern, efficient integrated gasification combined cycle technology.

To calculate kilograms of avoided emissions, we subtracted the total emissions from each energy source from the emissions of the baseline. For example, the total emissions of the IGCC plant with CO2 capture was 0.18956 kilograms per kwh, which was subtracted from 1.015 kilograms per kwh for the baseline coal plant, resulting in 0.82544 kilograms of avoided CO2 pollution.

Finally, for each energy source we divided the total system-wide cost per kwh by the total for avoided emissions per kilogram.

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