The Carbon Capture Conundrum: Public Need vs Private Gain

Assessing Atmospheric Carbon Dioxide Reduction from a Public Policy Perspective: A Review of the Literature

by

June Sekera and Andreas Lichtenberger

Executive Summary for Policymakers

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Abstract

Under the banner of "climate mitigation," the U.S. Congress has enacted legislation to subsidize technological-commercial "carbon dioxide removal" (CDR)[1]. Yet, a review of the scientific literature on CDR shows that, in practice, the methods Congress is supporting generally emit more CO_2 into the air than they remove. Lawmakers in the U.S. and elsewhere are considering further subsidies. Such legislation is based on a premise that carbon is a potential asset to be captured and sold. This finance-driven rather than science-driven approach to climate mitigation policy makes biophysics subservient to market concerns. A chief result has been subsidies for increased oil production using "anthropogenic" CO_2. In their actions, lawmakers are eschewing both science and public need. What is vital on both scores is not merely carbon "removal" but an absolute, *net reduction* of atmospheric CO_2.

Lawmakers inclined toward the market perspective can find support for technological-commercial CDR practices. Some scientific papers report that such procedures represent "climate mitigation" because they produce fewer carbon emissions than conventional oil production, and will "displace" conventional production. Other papers advance the argument that "negative emissions technologies" – such as direct air capture – can result in "net-zero" emissions. A central issue in many scientific studies is commercial viability: scientific papers that undertake a *financial* analysis find that the techno-industrial CDR procedures are not now commercially viable. Based upon a market frame, these papers call for government subsidies to develop a market for captured carbon, and, eventually, commercial profitability.

However, scientific studies that use a biophysical frame directly address the question of net CO_2 reduction. They show that the technological-commercial CDR procedures reviewed *are net atmospheric CO_2 additive* (that is, they emit more CO_2 than they remove). Our review of over 200 scientific studies on CDR revealed reasons for this apparent divergence of expert opinion. Studies by proponents of technological-industrial CDR methods miss crucial information for public policy-making. Some analyze only part of the CDR process "life cycle," omitting parts crucial to policymakers. Most base their "climate mitigation" conclusions upon "carbon accounting" schema that look at CO_2 flow rather than atmospheric stock, and invoke unsupported economics assumptions about "displacement" of conventional oil production.

Moreover, the scale of techno-commercial carbon capture and storage at this time is infinitesimal in relation to the scale of the problem. The preponderance of scientific literature elides or ignores the biophysical impacts and potential adverse effects of operating such procedures at the scale needed to avoid exceeding the international 1.5º C target limit for global warming: earthquakes prompted by vast volumes of CO_2 stored underground; groundwater contamination; "fugitive emissions" that pollute the air. Energy consumption at scale is also often slighted: one industrial CDR process would annually demand an amount of energy nearly equal to all electricity generated in the U.S. in 2017; another would require a land area 10 times the size of Delaware for energy generation alone. To upscale any of the methods in existing or pending legislation to a meaningful level of CO_2 reduction would entail the construction of an infrastructure and pipeline network far larger than that which now exists for fossil fuel production and delivery. Most studies also avoid discussion of the "wartime level of effort" that would be required to achieve CO_2 reduction at scale and in time to make a difference.

CDR legislation enacted to date and the 8 bills making their way through Congress now (see Appendix) do not support *biological methods* of carbon drawdown and sequestration. Preliminary research suggests that biological methods are not only more effective at atmospheric CO_2 reduction; they also provide co-benefits such as soil nutrient restoration, air and water filtration, fire management and flood control, and may also be more effective and efficient in terms of resource usage.

Executive Summary for Policymakers

Note: The full report can be found here.

Background

Removing carbon dioxide from the atmosphere as a means of climate change mitigation is gaining attention among U.S. lawmakers. Congress has passed legislation to subsidize industrial CO_2 removal methods, and lawmakers are taking up additional measures to finance further expansion. This legislative attention has powerful drivers: mounting concern about the acceleration of climate change and its widening impact; scientific reports that proffer negative emissions technologies (NETs) as an effective mitigation method; appeals by advocates for and investors[2] in industrial CDR[3]; the influence of fossil fuel interests[4]; advocates for prolonging fossil fuel production[5] (for example, via "clean coal" and "green oil"[6]); and oil companies seeking to acquire and hold CDR patents and intellectual property rights[7].

Carbon dioxide removal has been portrayed by the Intergovernmental Panel on Climate Change (IPCC) as necessary to avoid "overshooting" the internationally agreed-upon goal of limiting temperature rise to 1.5°- 2ºC.[8] Among scientists, and increasingly among the informed public, there is growing alarm about the rising atmospheric concentration of carbon dioxide, the "most important"[9] greenhouse gas driving global warming. Atmospheric CO_2 recently surpassed 400 parts per million (ppm). Before the industrial age the level was 280 ppm.[10] Globally, CO_2 annual emissions have reached nearly 37 billion tons[11], a level that scientists warn cannot be maintained or increased if we are to avoid exceeding the 1.5°-2°C threshold and the resultant climate change-driven harms.

There are multiple ways to remove and sequester atmospheric CO_2: biological methods as well as technological methods. Our paper deals only with the technological methods that have been adopted by commercial-industrial purveyors, because those have thus far enjoyed the most legislative success in the United States, even though many scientists and others argue that biological methods could be widely deployed and effective, **or that transitioning to non-carbon energy sources is the most fundamental need and would be the most fruitful path to take.**[12]

This report is designed for public policymakers – to help them "apply science to societal needs."[13]

"apply science to societal needs"

This study addresses collective need; hence -- in legislative terms -- public purpose. The scientific consensus is that there is excess CO_2 in the air; the collective need – hence, the public purpose – must be to *reduce* the amount of CO_2 in the air. While CDR technologies may "remove" CO_2, that is not the same thing as an overall *reduction* of atmospheric CO_2. Our paper illuminates scientific findings that have not previously been brought to the forefront for policymakers. Absent these findings, lawmakers and other public policymakers have been deprived of the necessary context within which to make informed decisions.

"Moral hazard, betting, and hubris"

"Three issues in particular stand out in need of future ethical analysis. These are first, that [negative emissions technologies] NETs might create a ***moral hazard*** against mitigation; second (and relatedly), that an implicit policy ***bet*** on NETs that are unproven at scale may lock in worse climate-related harms if they failed to deliver; and third, that the sheer scale of NETs deployment observed in mitigation scenarios is staggeringly ***hubristic***."

"There is an urgent need for the international community not to further increase but reduce its dependence on technologies for carbon removal from the atmosphere."

(Jan C. Minx et. al. 2018; and LaFollette News 2018)

CDR Methods Reviewed in the Report

- **Point-source carbon capture technologies: Carbon Capture and Storage (CCS;** also called Carbon Capture and Sequestration) and **Carbon Capture Utilization and Storage** (**CCUS**). Both CCS and CCUS capture carbon dioxide at a point of emissions, generally smokestacks. The captured CO_2 is either stored underground or used for commercial applications (e.g., for oil production via "enhanced oil recovery") or both. Note that "point-source" capture does not remove CO_2 already in the atmosphere.

- **Atmospheric carbon capture technologies: Direct Air Capture (DAC).** This process pulls carbon dioxide from ambient air by using fans to draw in the air and chemical processes to separate out the CO_2 for commercial use or sequestration.

No technological CDR method addresses the problem of other greenhouse gases, such as methane.

Figure 1 is a depiction of technological CDR methods.

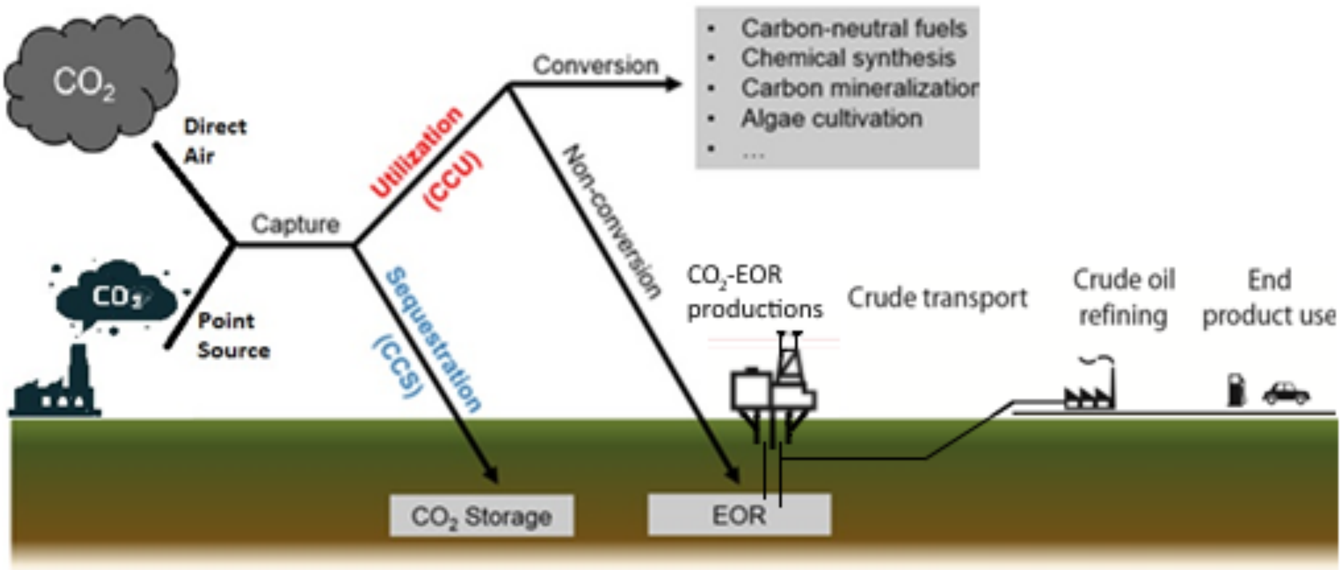

Figure 1. ***Technological Carbon Dioxide Removal*** *(Image credit: Adoption of Wikipedia depiction and Stewart & Haszeldine (2014) "Carbon Accounting for Carbon Dioxide Enhanced Oil Recovery", p 26)*

Principal Findings

- **Technological-commercial methods of CDR generally put more CO_2 into the atmosphere than they remove.** The two principal technological-commercial methods of CDR ("carbon capture and storage" with "enhanced oil recovery" [CCS-EOR] and "direct air capture" powered by fossil fuels) are net additive: they add more CO_2 into the atmosphere than they remove. Thus, in their very essence they are counter-productive in terms of the public purpose goal of *net atmospheric CO_2 reduction*. In the case of CCS/CCUS, this is largely because the captured carbon is primarily used to produce more oil. In the case of fossil-fuel-powered DAC, the counter-productivity is due to the large amount of energy required to power the machinery and process that capture the CO_2. CCS processes have been found to emit from 3.7 to 4.7 metric tons of CO_2 for every metric ton of CO_2 injected;[14] DAC has been found to emit from 1.5 to 3.4 tons of CO_2 for every ton captured.[15]

- **Captured CO_2 is used mainly to produce oil through "enhanced oil recovery" (EOR)** Advocates for public subsidy of industrial methods of CDR argue that government financing will foster the development of new commercial products,[16] like "carbon-neutral fuel" and "clean cement." In practice, captured CO_2 is almost always used to access more oil through CO_2-EOR[17] (also called CCS-EOR), which injects CO_2 into oil wells to squeeze out "stranded" oil. Moreover, there is no significant alternative demand for captured CO_2 now[18] or in the foreseeable near-future.[19] Indeed, direct air capture companies that had announced they would be using their captured CO_2 for such purposes as synfuels, carbonated beverages, or greenhouse aeration, are having difficulty finding customers. Some have already changed their plans and will be selling their captured CO_2 to the oil industry for EOR. For example, Carbon Engineering[20] has announced that it is partnering with Occidental Petroleum to build a new direct air capture plant in the Permian Basin (Texas) for EOR, an operation that will be partially taxpayer-financed by state and federal subsidies.[21] Another DAC startup – Global Thermostat – has announced plans to partner with ExxonMobil.[22]

> **"Calls for…CCS or CCUS…should primarily be understood to drive the expansion of enhanced oil recovery or the production of combustible fuels. This EOR, in turn, will necessarily lead to the increased production and consumption of oil, the increased GHG emissions that arise from its combustion, and increased investments in the infrastructure for producing, distributing, and using fossil fuels."**
> Center for International Environmental International Law; "Fuel to the Fire" (2019)

- **Public subsidy of industrial CDR promotes fossil fuel lock-in.** Near-term public subsidy of commercial CDR methods creates long-term "lock-in"[23] of the fossil fuel industry as holder of the expertise and owner of the infrastructure that would be critical should government decide to scale up CDR to a meaningful level. If and when it declares a "climate emergency," government would have to rely on the fossil fuel industry to solve the problem – for which their products were responsible.

- **Scaled to be meaningful for climate change mitigation, industrial CDR would require a wartime level of mobilization.** The scale of industrial carbon capture and storage at this time is infinitesimal in relation to the excess concentration of CO_2 in the atmosphere. Of the more than 200 scientific papers we reviewed, almost none acknowledge the level of effort that would be needed to scale up to significant[24] impact – an effort equivalent to "wartime mobilization" (Mac Dowell 2017) – or the infrastructural buildout: a vast new pipeline network necessary to transport the captured CO_2.[25] Most researchers who address the issue of scale frame it as a *financial* problem---a shortfall in financial investment that government must fill. Our analysis, instead, addresses the *biophysical* issues related to scale: the limited (or counter-productive) CO_2 impact of industrial-commercial CDR; the enormous amounts of energy and resources required; the "dis-benefits" that would arise from scaling up to a meaningful level.

  There is no consensus on the maximum concentration of atmospheric CO_2 that may avoid exceeding the 1.5°C or 2°C global temperature rise limit. Estimates have ranged from 350ppm[26] to 507ppm[27]. Regardless, billions of tons – "gigatons" (Gt) -- of CO_2 would need to be permanently removed. Mac Dowell et. al. (2017) calculate that **a global sequestration rate of 2.5 Gt of CO_2 per year is needed by 2030, increasing to 8 to 10 Gt per year by 2050.**

  Of the nearly 37 Gt of CO_2 emitted globally each year now, the U.S. emits roughly 5.3 Gt.[28] Viewed from this perspective, a removal rate of 2.5 GtCO_2 per year is a modest goal, and even so it would demand an enormous level of effort. (Although this paper is primarily focused on U.S. legislation and efforts, the purveyors of industrial-commercial CDR have global ambitions [Oil and Gas Climate Initiative 2019; Gunther 2011]).

- **Scaling up: enormous requirements for energy, land, infrastructure.** Reports on CDR often make an argument that oil-producing CCS and energy-devouring DAC should be subsidized by government as a "stepping stone" to more effective and efficient methods of climate mitigation. But such arguments elide the scaling-up problems. The "direct air capture" method of CO_2 removal, at scale, could demand a quantity of energy approaching the total annual electricity generated in the U.S. One estimate suggests that to remove 1 Gt of CO_2 from the ambient air could consume "3,417 terawatt-hours of electricity annually" -- "**an amount that is nearly equivalent to all electricity generated in the United States in 2017.**"[29] Other studies make similar estimates, ranging from 3,156 to 5,049 terawatt hours, and yet none of these estimates account for such downstream aspects of the DAC life cycle process as the energy and land requirements for the transport and sequestration of captured CO_2. Yet, if powered by renewable (solar) energy, DAC operating at minimal scale (1 Gt capture) would require **a land area ten (10) times the size of the state of Delaware**.

Another **land** requirement rarely mentioned in the scientific literature is the land needed for a vast pipeline infrastructure to transport the CO_2 to injections sites – whether for enhanced oil recovery or for sequestration underground. Figure 2 is from a report by CCS-EOR policy advocates who call for government subsidy of pipeline buildout. At scale the requirement is massive. One Gt of CO_2 capture **would entail CO_2 pipeline capacity more extensive than the entire fossil fuel pipeline system currently in place.** (See full report for details.)

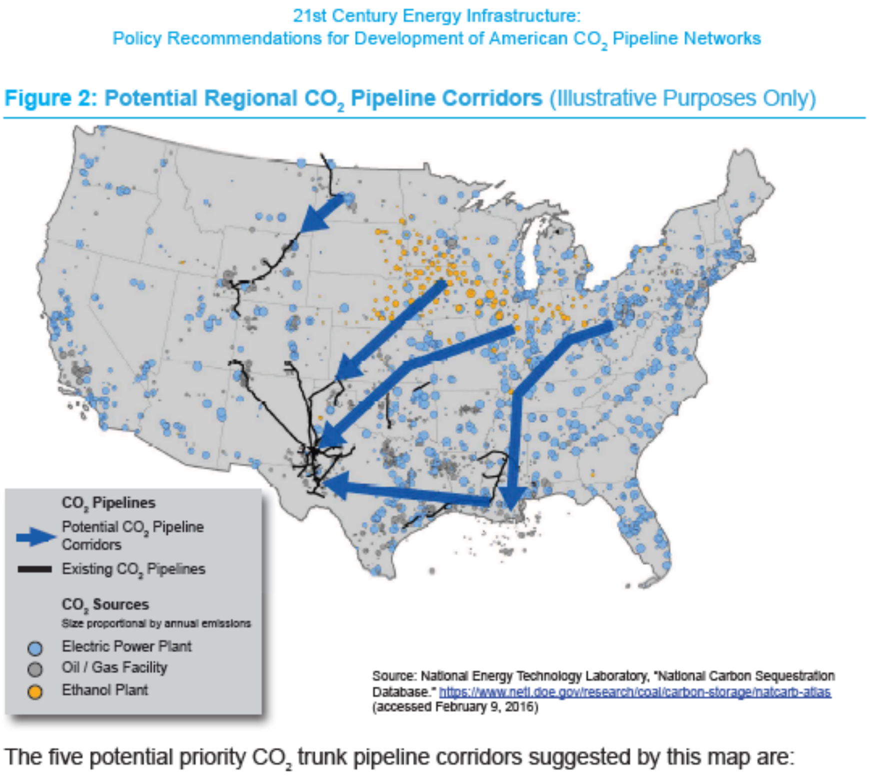

Figure 2: Recommendations for Publicly-Subsidized CO_2 Pipelines (Source: "State CO_2-EOR Deployment Work Group" 2017)

- **Above and below ground perils – the "disbenefits" of technological CDR infrastructure.** Among the potential "dis-benefits" found in the literature on technological-industrial CDR are:
  * **Blowouts** – of pipelines or failure of other equipment.
  * **Earthquakes** – resulting from underground storage of gas under high pressure
  * **"Fugitive emissions"** – leakage of gas from storage sites and pipelines
  * **Aquifer acidification**
  * **Air pollution and health damage**[30]

In theory, techno-industrial CCS, CCUS or DAC processes would eventually inject captured CO_2 into secure underground geological formations (except for the CO_2 that would theoretically be "utilized" for products). The security of such storage "facilities" would depend on their suitability for long term gas[31] storage as possibly affected by seismic activity. When captured CO_2 is used for EOR, the CO_2 is injected into an oil well, where it is meant to remain in perpetuity. Other locations for storage are saline formations (aquifers) and "unminable coal seams" (Herzog 2011). As the Congressional Research Service (2018) points out, potential storage caverns or strata must be scrutinized for **porosity, permeability, and the potential for leakage** – another major task.

Legislation would be required to assure that standards are in place to avert or reduce leakage and to limit the likelihood of earthquakes from storage sites. Diligent monitoring and constant government-funded oversight would be required to assure that those standards are respected and met. Experience thus far with the "45Q" tax credit for CCS already indicates discrepancies in industry reporting about how much CO_2 has actually been stored. Reviewing industry filings with government, Clean Water Action[32] discovered that companies reported one amount to the IRS – nearly 60 million tons of CO_2 – as captured (for their tax credits), and another much smaller amount to EPA – 3 million tons of CO_2 – as sequestered and stored.

- **Confusion, obfuscation and conflicts in reporting.** The scientific reports on technological-industrial CDR are often abstruse and contain conflicting conclusions. This inconsistency is due to several factors: the use, in some cases, of selective "carbon accounting" schema; differing study objectives; and partial "life cycle analysis" used in some studies. Some research is expressly designed to determine the extent to which the production of more oil through CO_2 -EOR may paradoxically produce "climate mitigation". Some reports are written by scientists with a financial interest in CDR businesses. **Only "cradle to grave" life cycle analyses -- looking at where CO_2 starts out and where it ends up, and how much is generated from the overall process – are relevant for public purpose.**

- **Is CO_2 a commodity to be captured and sold, or a substance to be sequestered?**

  In their final analyses, the majority of papers on techno-industrial CDR methods are market-centric, oriented around the presumption that carbon is a potential asset to be captured and sold. Government's role is seen as market-making: subsidize the development of CDR technologies ostensibly so that they can reach commercial viability, and remove regulatory barriers (e.g., for pipeline construction).

  The alternative is to focus on the societal need: Reduce atmospheric CO_2 as safely and expeditiously as possible. This means sequestering – not selling – CO_2. Climate mitigation is not a market matter.[33] CDR cannot work as a profit-generating enterprise if it is to succeed in *actually reducing* atmospheric CO_2. Carbon dioxide *reduction* is a public service to meet an urgent public need.[34] The CO_2 must simply be sequestered. If CDR technologies are publicly financed, then the accompanying or resultant intellectual property and patents should be held in the government's name. (See full paper for further discussion.)

  Moreover, in terms of point-source capture, no public subsidies should go to CCS. In economics terminology, harmful power-plant emissions are a "negative externality". The cost of ending or preventing these "negative externalities" should be borne by the producer.[35]

- **Legislative action is needed.**

As noted earlier, industrial-commercial CDR methods generally emit more CO_2 into the atmosphere than they remove. Yet these counterproductive methods have been subsidized under legislation passed in 2018, and would be further subsidized with pending legislation (see Appendix).

For immediate action:

In order to restrict public subsidies to methods that are net CO_2 *reductive*, **Congress could include language along the following lines in any CDR legislation:**

1. **"No funding appropriated, or tax liability reduced, under this Act may be used to support any process related to enhanced oil recovery, or for any other process that results in the production of fossil fuels."**

2. "No funding appropriated, or tax liability reduced, under this Act may be used to support any CO_2 direct air capture process that uses fossil fuel as its power source."

3. "No funding appropriated, or tax liability reduced, under this Act may be used to support any process in which the CO_2 emitted by the process exceeds the CO_2 removed by the process over its entire life cycle."

This standard can be expressed as a ratio: $\frac{CO_2 \text{ emitted by the process}}{CO_2 \text{ removed by the process}}$

A ratio greater than 1 means that the process adds more CO_2 to the atmosphere than it removes.

- **Longer-term: we need research that compares and evaluates biological vs technological methods**

As things now stand, policymakers -- and the public – have been deprived of the necessary context in which to evaluate the full range of choices for CDR. Lawmakers cannot easily do their "due diligence." Providing this context would entail an assessment of the capabilities and limitations of biological methods as compared with the techno-industrial methods discussed here. The comparison must be on an apples-to-apples basis, e.g., examining net carbon balance impact and standardizing for output in order to compare inputs required. **Such a comparison does not yet exist.** The questions to be addressed are:

1. **Net carbon balance:** does the process *remove* more CO_2 than is *emitted* by the process?
2. **Resource usage:** how much *energy* is consumed by a process? how much *land* is required?
3. **Ancillary effects:** what are the side effects of the process – its co-benefits or dis-benefits?

Once answered for each biological and techno-industrial method, a tool for effective comparison could be constructed:

- **Resource Return on Resource Inputs (RRORI)** [36]
  What is the "return" on the resource inputs of energy and land in terms of:
  a) atmospheric carbon dioxide reduction?
  b) other biophysical gains or losses?

The development of a "Resource Return on Resource Investment" (RRORI) tool could serve as a basis for setting standards for public policy formulation on CDR.

* * *

Note: The full report can be found here.

Addendum:

Biological Methods of Carbon Dioxide Removal and Sequestration

Biological methods of CDR are based on processes that naturally remove CO_2 from the atmosphere and sequester it in soil and biomass. These include:

- **Forests:** reforestation, afforestation, forest management and averting deforestation.
- **Farming:** soil and biomass carbon sequestration through regenerative farming and other improved agricultural methods.
- **Grasslands:** restoration.
- **Wetlands:** restoration.

Preliminary research suggests that biological methods of carbon drawdown and sequestration are not only more effective than commercial CDR technologies at atmospheric CO_2 reduction; they also provide documented co-benefits such as soil nutrient restoration, air and water filtration, fire management and flood control, and may also be more effective and efficient in terms of resource usage.

A graphical representation of biological systems for CDR is depicted in Figure 3.

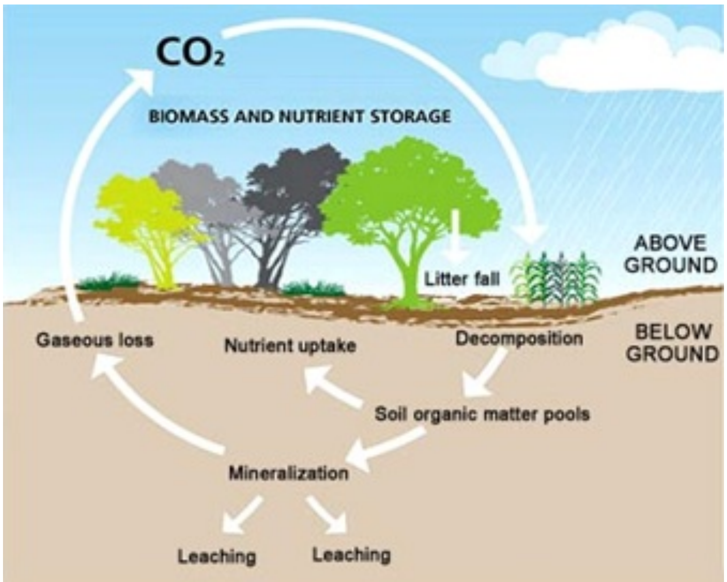

Figure 3. ***Biological Systems for Carbon Dioxide Removal and Sequestration*** *(Image credit: https://climatechange.lta.org/enhancing-carbon-sequestration/)*

However, biological methods of carbon dioxide sequestration are not the subject of the present paper because it is technological-industrial methods that have gained legislative traction in the U.S. Further work is needed to compare technological and biological methods on a standardized basis.

Appendix

Carbon Dioxide Removal Legislation
Passed by or Pending in the U.S. Congress

The U.S. Congress in 2018 enacted a significant expansion of an existing tax credit for carbon dioxide removal. This expanded "**45Q" tax credit**[1] loosened the qualifications and increased the subsidy for industrial-commercial carbon capture. One source at the time predicted that the legislation would likely be "the largest subsidy given to the fossil fuel industry by the United States government."[2] Additional federal subsidies moving through Congress are summarized below.

Legislation Passed

45Q tax credit

Enacted in 2018

Expanded and extended a previous tax credit for carbon capture: tripled the amount of the tax credit; removed a cap on CO_2 tonnage qualifying for the credit; extended the credit to direct air capture.[3] Of special note is that 45Q incentivizes counter-productive practices in terms of atmospheric CO_2 reduction because "Under 45Q, selling to EOR is more profitable than…sequestration.[4]

Legislation Pending

USE IT Act (Utilizing Significant Emissions with Innovative Technologies Act)[5]

Provides public funding for:
* commercial development of carbon capture;
* promotion and development of direct air capture for private sector and commercial uses;
* facilitating the construction of pipelines for CO_2 transport;
* use of captured carbon for Enhanced Oil Recovery.

EFFECT Act (Enhancing Fossil Fuel Energy Carbon Technology Act)

The EFFECT ACT would direct the Department of Energy's Office of Fossil Energy to establish four new research and development programs focused on coal and natural gas technology, carbon storage, carbon utilization, and carbon removal.

Following is from senate.gov[6]

The EFFECT Act would expand the DOE's fossil energy research and development (R&D) objectives and establish new R&D programs for carbon capture, utilization, storage, and removal, including:

- A Coal and Natural Gas Technology Program for the development of transformational technologies to improve the efficiency, effectiveness, costs, and environmental performance of coal and natural gas use.
- A Carbon Storage Validation and Testing Program to conduct research, development and demonstration for carbon storage and establish a large-scale carbon sequestration demonstration program, with the possibility of transitioning to an integrated commercial storage complex.
- A Carbon Utilization Program to identify and assess novel uses for carbon, carbon capture technologies for industrial systems, and alternative uses for coal.
- A Carbon Removal Program for technologies and strategies to remove atmospheric carbon dioxide on a large scale, including an air capture technology prize competition.

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[1] An environmentalist analysis of the 45Q legislation: Expanding Subsidies for CO2-EOR. An industry summary: Three Things to Know.
[2] Redman 2017 http://priceofoil.org/2017/10/24/expanding-subsidies-for-co2-enhanced-oil-recovery-a-net-loss-for-communities-taxpayers-and-the-climate/
[3] National Law Review (2019) "Enhancements to the New Section 45Q Tax Credit" May 3, 2019.
[4] Matt Lucas (2108) "45Q Creates Tax Credits for carbon capture. Who benefits?" Carbon 180.
[5] USE IT Act (S.2602), U.S. Senate ; Rathi, Akshat (2018) "A bipartisan US group introduced another bill to support a controversial climate technology" qz.com April 1, 2018;
Barrasso, John, U.S. Senator (2019) "USE IT Act: Reducing Emissions Through Carbon Use Innovation, Not Regulation"; March 18, 2019; Carbon Capture Coalition Hails Bipartisan Introduction of the USE IT Act Feb. 13, 2019
[6] https://www.energy.senate.gov/public/index.cfm/2019/4/manchin-murkowski-capito-cramer-daines-bill-authorizes-full-suite-of-carbon-capture-utilization-storage-and-removal-technology-programs

Fossil Energy Research and Development Act of 2019

This bill expands Department of Energy (DOE) research, development, and demonstration programs for fossil energy.[7] The bill authorizes DOE programs including:

- carbon capture technologies for power plants, including technologies for coal and natural gas
- carbon storage
- carbon utilization, including to assess and monitor potential changes in life cycle carbon dioxide and other greenhouse gas emissions
- carbon dioxide removal from the atmosphere

LEADING Act of 2019 (Launching Energy Advancement and Development through Innovations for Natural Gas Act)[8]

This bill is intended to make carbon capture commercially viable. It directs the Department of Energy (DOE) to establish a program to award funding to construct and operate facilities for capturing carbon dioxide produced during the generation of natural gas-generated power.

Carbon Capture Improvement of 2019

Amends the Internal Revenue Code to provide for the issuance of tax-exempt facility bonds for the financing of carbon dioxide capture facilities.[9]

Clean Industrial Technology Act of 2019

The "Clean Industrial Technology Act of 2019" is meant to: "incentivize innovation and to enhance the industrial competitiveness of the United States" and would support "carbon capture technologies" for this purpose.[10]

SEA FUEL Act, 2019 (Securing Energy for our Armed Forces Using Engineering Leadership Act) [11]

Provides funding for research and deployment of direct air capture and blue carbon technologies and conversion to fuels and other materials. Directs the Departments of Defense and Homeland Security to "pioneer" these technologies.

CLEAN Future Act (Climate Leadership and Environmental Action for our Nation's Future Act; 2020)[12]

Would provide several types of subsidies and incentives for technological-commercial CDR, and establish a program for taxpayer-funded purchases of low-carbon industrial products (which could be made with captured CO_2.) The proposed legislation also contains numerous other provisions unrelated to CDR; the bill is meant to be an alternative to the Green New Deal[13] (Grandoni 2020).

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[7] Congress.gov Fossil Energy Research and Development Act of 2019
[8] Congress.gov Launching Energy Advancement and Development through Innovations for Natural Gas Act of 2019
Senator Crenshaw website: Crenshaw Introduces Bipartisan Carbon Capture Legislation
[9] Congress.gov Carbon Capture Improvement Act of 2019
[10] Congress.gov The Clean Industrial Technology Act of 2019
[11] "Bipartisan Bill to Improve Military's Energy Security Included in NDAA"; December 17, 2019; https://www.whitehouse.senate.gov/news/release/bipartisan-bill-to-improve-militarys-energy-security-included-in-ndaa
[12] Clean Future Act legislative framework Memo.
[13] The Green New Deal Resolution supports biological methods of carbon drawdown and sequestration.

Endnotes

See the Bibliography in the full report for a list of all references.
The full report can be found here.

[1] We use the term “carbon dioxide removal” (CDR), because it is being widely adopted in international discussions of atmospheric carbon dioxide reduction. The term “negative emissions technologies” (NETs) is often used interchangeably with CDR in much of the literature. However, note that these terms do not include “geo-engineering,” which refers to interventions, like solar radiation management (SRM), designed to limit the amount of sunlight/energy reaching the planet’s surface. This distinction is also consistent with the 2015 report of the National Academies of Sciences on “Climate Intervention”.

[2] Some “Direct Air Capture” investors & ventures: Bill Gates, Occidental Petroleum, Chevron -- Carbon Engineering ; Seagram’s heir Edgar Bronfman Jr. -- Global Thermostat; Gary Comer, Lands End Founder -- Kilimanjaro Energy.

[3] Gunther 2011, Gunther 2012, Vidal 2018, Chalmin 2019, Rhodium Group 2019, Chichilnisky 2019, Mufson 2019, Temple 2019, Nagabhushan and Thompson 2019, Diamandis 2019.

[4] Marshall 2019; Morgan 2019, Muffett and Feit 2019, Cresswell 2019, ExxonMobil 2019a, Tabuchi 2019.

[5] E.g., see Realmonte et. al., (2019): “Moreover, DACCS enables delaying the phaseout of fossil-based electricity generation until after 2050;”and Mendelevitch (2013).

[6] U.S. Dept. of Energy (2017) “Two DOE-Supported Projects Receive Awards for Carbon Capture Technologies”, December 7, 2017; Hackett, Dave, Stillwater Associates (2018) “Carbon Capture and Utilization for Enhanced Oil Recovery, March 28, 2018; Azzolina, NA, Peck, WD, Hamling, JD, Gorecki, CD (2016). “How green is my oil? A detailed look at greenhouse gas accounting for CO2-enhanced oil recovery (CO2-EOR) sites” *International Journal of Greenhouse Gas Control*, Vol 51, 369–379.

[7] Soltoff 2019, ExxonMobil 2019b; Parsons 2018

[8] See, e.g., IPCC reports of 2014 and 2018: Intergovernmental Panel on Climate Change (2014) *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press. Intergovernmental Panel on Climate Change (2018) *Global Warming of 1.5°C; Summary for Policymakers*; October 2018. https://www.ipcc.ch/sr15/chapter/spm/

[9] “So far as radiative forcing of the climate is concerned, the increase in carbon dioxide has been the most important (contributing about 60% of the increased forcing over the last 200 years)…” pg xxxvii; Intergovernmental Panel on Climate Change (1990) *Climate Change: The IPCC Scientific Assessment*, Cambridge University Press.

[10] World Economic Forum https://www.weforum.org/agenda/2019/06/chart-of-the-day-these-countries-create-most-of-the-world-s-co2-emissions/

[11] Global Carbon Project; “Global Carbon Budget” https://www.globalcarbonproject.org/carbonbudget/19/highlights.htm. Also: “Global greenhouse gas emissions will hit yet another record high this year”; Chris Mooney & Brady Dennis, *Washington Post*, Dec. 3, 2019.

[12] There is a vast literature on this position, too voluminous to cite here.

[13] Chabbi et al 2017.

[14] If CO_2 captured at a source (e.g., a smokestack or any “point source”) is injected underground to boost oil production (i.e. for “enhanced oil recovery”), studies show that the overall CCS process emits more CO_2 than it removes. Studies indicate that the process emits 1.5 to 4.7 times as much CO_2 as it removes. The 1.5 calculation is from Azzolina et. al. (2016) without integration of the “displacement’ postulate. The 4.7 calculation is from Jaramillo et. al. (2009). Also see Armstrong and Styring (2015), Dismukes et. al. (2018) and ScottMadden (2018).

[15] This range refers to Direct Air Capture. Based on Smith et al. 2016 pg 47: 156 EJ/yr required to capture ~3.3 Gt Ceq/yr. Calculations performed by S. Davis. 8-19-19; personal communication. Calculations showed the emissions ratio associated with gas as the DAC power source to be 1.46 to 1 [rounded to 1.5 to 1); the ratio with coal as DAC power source is 3.44 to 1. Alternatively, renewable energy sources could be used, which could result in net reduction of atmospheric CO_2. However, the question is whether renewable energy power should be consumed by DAC rather than used for direct energy production for the nation.

[16] For example: Steven J. Davis et. al. (2018) “Net-zero emissions energy systems”, *Science 360.*

[17] Foehringer Merchant, Emma, “With 43 Carbon-Capture Projects Lined Up Worldwide, Supporters Cheer Industry Momentum,” Greentechmedia, Dec. 11, 2018. Also when reviewing large-scale CCS projects in the U.S. at the CCS website, all projects are EOR-related (https://co2re.co/FacilityData).

[18] Foehringer Merchant, Emma, “With 43 Carbon-Capture Projects Lined Up Worldwide, Supporters Cheer Industry Momentum,” Greentechmedia, Dec. 11, 2018. Also when reviewing large-scale CCS projects in the U.S. at the CCS website, all projects are EOR-related (https://co2re.co/FacilityData).

[19] See e.g., Mac Dowell et. al. (2017); Schafer et. al. (2015) and CIEL (2019) *Fuel to the Fire*

[20] A DAC startup in which Bill Gates originally invested (Vidal 2018, Morgan 2019, Gunther 2011).

[21] The facility “will be designed to qualify for both the US federal 45Q tax credits, and California’s Low Carbon Fuel Standard credits.” “Oxy and Carbon Engineering partner to Combine Direct Air Capture and Enhanced Oil Recovery storage.”

[22] James Temple; “Another major oil company tiptoes into the carbon removal space” MIT Technology Review June 28, 2019. “ExxonMobil’s deal with a startup developing ways to suck carbon dioxide from the air marks another sign of the oil and gas sector’s growing interest.”

[23] Re: “carbon lock-in”, see: SEI, IISD, ODI, Climate Analytics, CICERO & UNEP (2019) and Erickson et. al. (2015).

[24] Mac Dowell et. al., (2017) calculate that a rate of sequestration of 2.5 Gt per year is needed by 2030, increasing to 8-10 Gt CO_2 per year by 2050, and escalating after that.

[25] Some authors claim that direct air capture would not require a vast pipeline buildout because CO_2 can be drawn out of the air anywhere, but others note that pipelines would still be needed to transport the captured CO_2 to suitable underground storage locations.

[26] Bill McKibben citing esteemed NASA scientist James Hansen in 2007. McKibben, Bill (2007) "Remember This: 350 Parts Per Million" *Washington Post*, Dec. 28, 2007.

[27] "How much CO2 at1.5° C and 2° C?" July 2018, https://www.metoffice.gov.uk/research/news/2018/how-much-co2-at-1.5c-and-2c

[28] Fleming, Sean (2019) "Chart of the day: These countries create most of the world's CO2 emissions"; World Economic Forum, 7 June 2019. https://www.weforum.org/agenda/2019/06/chart-of-the-day-these-countries-create-most-of-the-world-s-co2-emissions/

[29] Climate Advisers (2018).

[30] Jacobson (2019).

[31] "Mineralization" of CO_2 -- "solid storage" -- is also discussed in the literature as a possibility. But there are hurdles; the feasibility of this approach is uncertain; and carbon dioxide removal at scale could result in burying "mountains" of solidified carbon. (Clemens 2019; Barnard 2019).

[32] John Noel (2018) Carbon Capture and Release: Oversight Failures in Section 45Q Tax Credit for Enhanced Oil Recovery; Clean Water Action; May 2018.

[33] See: Missing in the Mainstream; Sekera (2017).

[34] CO_2 has been classified as a pollutant under the Clean Air Act; see Supreme Court rulings in 2007 and 2014. Subsequently, the EPA issued rules regulating CO2 as a pollutant. Still, some argue that CO_2 is should instead be viewed as a valuable commodity. Scientists and journalists have reported on CO_2 as a "waste" and the need for "waste disposal", and on the view of carbon dioxide removal as a public service, or a "public good". See: Kolbert, Elizabeth (2017) "Can Carbon-Dioxide Removal Save the World?" *New Yorker*, Nov. 20, 2017; Buck, Holly Jean (2018) "The Need for Carbon Removal" *Jacobin Magazine*, July 2018; Mulligan, James, Ellison, Gretchen, Gasper, Rebecca & Rudee, Alexander (2018b) "Carbon Removal in Forests and Farms in the United States," *World Resources Institute,* Sept. 2018; Magill, Bobby (2016) "CO2, Climate Change Seen As Waste Disposal Challenge" *Climate Central*, Sept. 13, 2016. Re: Supreme Court decisions, see National Resources Defense Council (2007) and Barnes (2014).

[35] Most fossil-fueled power plants do not perform carbon capture presently in large part because of the added expense. CCS equipment "cannibalizes up to a third of the power produced" (Heinberg 2018) – that is, the power plant must either generate extra power to run the carbon capture machinery, or take a loss in terms of the quantity of power produced for sale.

[36] This concept borrows from the concept of "EORI" – Energy Return on Investment – developed by systems ecologist Charles A.S. Hall.