# DIRECT AIR CAPTURE FACILITIES AND PRODUCTION OF CARBON-NEUTRAL HYDROCARBONS

by Neil Segel

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## SUMMARY

**The United States has introduced increasingly stronger measures to incentivize production of low-carbon synthetic fuels and to provide tax credits for carbon-dioxide utilization from direct air capture (DAC) projects. While this federal action has made substantial progress, it has not adequately kept pace with developments in carbon capture and sequestration and DAC technologies that produce low-carbon synthetic fuels. This Article aims to provide guidance on how the federal regulatory framework can draw level to the technological advancements, and proposes changes in two areas. First, it recommends that federal agencies amend existing regulations and guidelines to provide stronger monetary incentives for DAC projects. Second, it recommends modifying key legislation to allow the government to approve broader fuel pathways. These adaptations will allow for a smoother and more expedient transition to a lower-carbon future.**

Growing demand for increasingly deeper decarbonization will drive industrial changes in the decades to come. Global population and gross domestic product will grow rapidly, and most outlooks anticipate a 25% to 30% increase in global energy demand by 2040.[1] This growth in energy demand and resultant production presents a "dual challenge of providing affordable, reliable energy while addressing the risks of climate change."[2]

Anthropogenic activities account for almost all of the increase in greenhouse gases (GHGs) in the earth's atmosphere over the past 150 years.[3] It is imperative that government and private industry alike work hand-in-hand to address the concerning rise of atmospheric GHGs to stave off climate change as much as possible. To the extent that these ambient GHG levels "lock in" certain anthropogenic changes to earth's climate, the foremost step is to mitigate current emissions. In addition, however, decarbonization will require not just net-neutral, but net-negative solutions. To achieve a net-negative goal, it is essential to bridge that divide with net-neutral technological adaptation through certain directed policies.

In the 2015 Paris Agreement, the international community committed itself to limiting global warming by the year 2100 to "well below 2ºC," and "to pursue efforts to keep warming below 1.5ºC" compared to pre-industrial levels.[4] The United Nations' Intergovernmental Panel on Climate Change modeled hundreds of emissions scenarios and found only 76 pathways that could attain these tar-

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1. *See* BP, BP Energy Outlook: 2019 Edition (2019), https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2019.pdf; ExxonMobil, 2019 Outlook for Energy: A Perspective to 2040 (2019), https://corporate.exxonmobil.com/-/media/Global/Files/outlook-for-energy/2019-Outlook-for-Energy_v4.pdf; International Energy Agency, World Energy Outlook 2019 (2019) (Stated Policies Scenario), https://www.iea.org/reports/world-energy-outlook-2019.
2. 1 National Petroleum Council, Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage 30 (2019), https://dualchallenge.npc.org/files/CCUS_V1-FINAL.pdf.
3. Intergovernmental Panel on Climate Change, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Susan Solomon et al. eds., 2007), https://www.ipcc.ch/site/assets/uploads/2018/05/ar4_wg1_full_report-1.pdf.
4. *Adoption of the Paris Agreement*, U.N. FCC, U.N. Doc. FCC/CP/2015/L.9 (2015), https://treaties.un.org/doc/Treaties/2016/02/2016021506-03PM/Ch_XXVII-7-d.pdf.

gets.[5] Of these 2°C pathways, 87% of them rely on the assumption of large-scale atmospheric carbon dioxide ($CO_2$) removal (CDR) from the ambient atmosphere, reaching net-zero emissions at some point in the 21st century followed by a period of net-negative emissions, where CDR rates would exceed residual emissions.[6]

According to the U.S. Environmental Protection Agency (EPA), the transportation sector generates the largest share of anthropogenic GHG emissions, entailing 28.2% of 2018 total GHG emissions.[7] These GHG emissions from transportation primarily come from burning fossil fuel for cars, trucks, ships, trains, and planes. More than 90% of the fuel used for transportation is petroleum-based and is primarily gasoline and diesel.[8] To address the need for deeper decarbonization, it is essential both to capture the single largest carbon-emitting sector's emissions and to initiate necessary interim measures to neutralize carbon emissions[9] without overly disrupting existing transportation systems—which do not necessarily require liquid hydrocarbon fuels.[10] To do so will require active government intervention to better incentivize and subsidize enormous capital development and operational overhead costs.

A promising and rapidly developing area addressing transportation sector-based $CO_2$ emissions is the development of direct air capture (DAC) technologies and their ability to aid in the production of clean-burning synthetic carbon-neutral hydrocarbons (CNHCs). DAC technologies refer to "any industrialized and scalable methods to remove greenhouse gases from the ambient atmosphere and either store or reuse those gases in a way that does not allow them to escape back into the atmosphere."[11]

One of the most promising features of DAC technologies is that they are able to extract $CO_2$ from ambient air at any location on the planet because $CO_2$ is nearly evenly distributed around the globe. Untethered from the requirement of co-locating point source carbon capture around existing emissions sources (such as flue gas capture from industrial plants), the infrastructure requirements for DAC are more flexible, and can be manipulated based on localized economic factors. The sequestration of captured carbon, however, does present potentially high transmission costs and legal permitting issues,[12] depending on the final destination and use.[13]

Location-independent capture and sourcing of $CO_2$ would significantly reduce legal permitting barriers, transport costs, as well as emissions resulting from transportation. Location independence would allow for synthetic fuel production to be performed at locations with the most favorable renewable energy prices. "A cost advantage of just 1 [cent per kilowatt hour] ct/KWh could offset or even overcompensate any potential extra costs of $CO_2$ derived from DAC compared to . . . $CO_2$ captured from industrial point-source emissions."[14] DAC as a feedstock for "power-to-X" (PtX) technologies would allow cities to produce their own synthetic, hydrogen-based fuels.[15]

Comparing configurations in presently operational DAC facilities, there exists minimal variety in terms of design structure and process elements. However, there are many proposals that seek to address localized needs and design constraints. The proposed configurations vary in their treatment of power system, oxygen supply, and $CO_2$ compression.[16] Several variations have been optimized to provide $CO_2$ for direct fuel synthesis.

For example, Carbon Engineering is developing "air-to-fuel" systems in which the hydrogen required as feedstock for the fuel synthesis step is produced by electrolysis.[17] In such a configuration, the oxygen from electrolysis is sufficient to supply the DAC facility's needs, so there is no need for an air separation unit in the DAC process, thereby cutting costs.[18] The advantage of a fuel synthesis system is

5. Tracy Hester, *Legal Pathways to Negative Emissions Technologies and Direct Air Capture of Greenhouse Gases*, 48 ELR 10413, 10413 (May 2018), https://elr.info/news-analysis/48/10413/legal-pathways-broad-use-negative-emissions-technologies-and-direct-air-capture-greenhouse-gases.
6. Christoph Beuttler et al., *The Role of Direct Air Capture in Mitigation of Anthropogenic Greenhouse Gas Emissions*, 1 Frontiers Climate 1 (2019), https://www.frontiersin.org/articles/10.3389/fclim.2019.00010/full; *see also* Intergovernmental Panel on Climate Change, Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Ottmar Edenhofer et al. eds., 2014), https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf.
7. U.S. EPA, *Sources of Greenhouse Gas Emissions*, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (last updated Dec. 4, 2020).
8. *See* Suzana Kahn Ribeiro et al., *Transport and Its Infrastructure*, *in* Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 323 (Bert Metz et al. eds., Cambridge Univ. Press 2007), https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg3_full_report-1.pdf.
9. As a penultimate step toward a carbon-neutral transportation system.
10. That is to say production volume relative to overall demand needs.
11. Hester, *supra* note 5, at 10413.
12. See Hester, *supra* note 5, at 10426-29, for a summary of legal obligations arising from negative emissions technology (NET) wastes and emissions, particularly addressing the nexus of managing and disposing of captured $CO_2$ with the federal Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation, and Liability Act, and the Safe Drinking Water Act.
13. For example, transmission costs may be high for $CO_2$ deposition in offshore saline aquifers or onshore geologic formations, versus compression and interim in situ tank storage, or compression and electrolysis for in situ fuel synthesis.
14. Beuttler et al., *supra* note 6, at 4-5.
15. *Id*. ("Together with its partners, Climeworks has demonstrated the viability of large-volume energy storage through PtX technology in real-life applications," including synthetic fuel production and producing synthetic building materials made from atmospheric $CO_2$.).
16. David W. Keith et al., *A Process for Capturing $CO_2$ From the Atmosphere*, 2 Joule 1573, 1582 (2018), *available at* https://www.cell.com/joule/fulltext/S2542-4351(18)30225-3?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS2542435118302253%3Fshowall%3Dtrue.
17. *See* George A. Olah et al., *Chemical Recycling of Carbon Dioxide to Methanol and Dimethyl Ether: From Greenhouse Gas to Renewable, Environmentally Carbon Neutral Fuels and Synthetic Hydrocarbons*, 74 J. Organic Chemistry 487, 492 (2009), *available at* https://pubs.acs.org/doi/pdf/10.1021/jo801260f?:

> Electrolysis is energy intensive . . . in water electrolyzers . . . the cost of electricity has been estimated to represent about 80% of the cost of hydrogen produced, while capital investment represented only 11%. In large electrolysis units, the cost of electricity would therefore dictate the overall economics and will be the major driving factor for producing hydrogen. The electricity needed for the process can be provided by any form of energy [e.g., geothermal, wind, solar, etc.].

18. Keith et al., *supra* note 16, at 1582.

that it requires a lower $CO_2$ supply pressure, thereby reducing the cost and complexity of the $CO_2$ compression and output cleanup.[19] Carbon Engineering is also developing methods to integrate the DAC and fuel synthesis, which is itself a promising area of research and development (R&D) that could lead to future deployment of globally dispersed DAC fuel stations.

The capture of ambient atmospheric $CO_2$ through DAC provides a renewable, cyclically neutral, and virtually inexhaustible carbon source that can allow the continued use of derived carbon fuels.[20] In this way, DAC technology can contribute to the development of a circular economy independent from fossil hydrocarbons. As DAC facility deployment increases, DAC could complement this circular economy by geologically sequestering "excess" $CO_2$ captured. For designated-use $CO_2$, recycling via chemical reduction with hydrogen can produce a variety of CNHC fuels of similar molar mass, such as octane, methanol,[21] and/or dimethyl ether (DME, also known as methoxymethane).[22]

The production of synthetic fuels via $CO_2$ hydrogenation could replace current automobile gasoline and diesel fuel, a concept that has been referred to as the "methanol economy."[23] This concept obviates the need to drastically alter the nature of existing energy use, storage, and transportation infrastructure.[24] These synthetic CNHC fuels would have to satisfy regulatory requirements under Title II of the federal Clean Air Act (CAA),[25] which includes stringent limits on the qualities and components of fuels commercially marketed to be burned for energy.[26] Upon their combustion and use, methanol, DME, and other DAC-produced synthetic CNHCs would form only $CO_2$ and $H_2O$ (water),[27] thus resulting in an achievable pathway toward conforming with Title II's existing standards, subject to fuel production processes that may create volatile organic compounds and nitrogen oxide (NOx) emissions.[28]

The production of CNHCs from DAC of $CO_2$ will enable a more rapid closure of the carbon budget gap. At present, the carbon budget amounts to about 1,100 gigatons (Gt) of $CO_2$.[29] For reference, of the 49 (±4.5) Gt emitted per year in total anthropogenic GHG emissions in 2010, $CO_2$ was—and continues to be—the major GHG accounting for 76% (38±3.8 Gt $CO_2$ per year) of total anthropogenic GHG emissions.[30] Global carbon capture,

19. *Id.*
20. Much remains to be determined about the potential carbon removal budget and the implications of increasingly higher $CO_2$ removal on atmospheric and terrestrial conditions. Obviously, a certain amount of atmospheric $CO_2$ is essential to keep in heat and facilitate photosynthesis.
21. DOE Office of Energy Efficiency and Renewable Energy, *Alternative Fuels Data Center: Methanol*, https://afdc.energy.gov/fuels/emerging_methanol.html (last visited Mar. 25, 2021) (methanol is considered an alternative fuel under the Energy Policy Act of 1992; as an engine fuel, methanol has chemical and physical fuel properties similar to ethanol); *see also* Alan Ingham, *Reducing the Carbon Intensity of Methanol for Use as a Transport Fuel*, 61 Johnson Matthey Tech. Rev. 297 (2017), *available at* https://www.technology.matthey.com/article/61/4/297-307/ ("The carbon intensity of methanol used as a transport fuel is lower than gasoline under all production methods and can produce lower GHG emissions than ethanol."); *see also* Leslie Bromberg & Wai K. Cheng, Massachusetts Institute of Technology, Methanol as an Alternative Transportation Fuel in the US: Options for Sustainable and/or Energy-Secure Transportation (2010), https://afdc.energy.gov/files/pdfs/mit_methanol_white_paper.pdf; Richard Bechtold et al., Methanol Institute, Use of Methanol as a Transportation Fuel 7-8 (2007), http://www.methanol.org/wp-content/uploads/2016/06/Methanol-Use-in-Transportation.pdfhanol-Use-in-Transportation.pdf:

    > The Clean Air Act (CAA) Amendments of 1990 envisaged that there would be a move toward vehicles designed to run on methanol, either neat or as M85, to meet various special programs for alternative fuel vehicles (AFVs), including the Clean Fuel Fleet (CFF) Program and the California Pilot Test Program. . . . Frustrated with the lack of progress in use of AFVs, Congress enacted limited fleet AFV acquisition requirements in the Energy Policy Act of 1992 which also contemplated methanol vehicle use. But initial implementation of this program coincided with the runaway methanol demand for methyl tertiary butyl ether (MTBE) use within the [Reformulated Gasoline (RFG) program established by the 1990 CAA Amendments] and associated runaway prices so methanol vehicles were largely ignored in these AFV programs that had been designed with them in mind. . . . [Subsequently, the] Energy Policy Act of 2005 eliminated the oxygen requirement for RFG while imposing a "Renewable Fuel Standard," essentially a requirement for use of increasing volumes of ethanol by refiners. Absent the RFG oxygen requirement . . . all major U.S. refiners [ceased] blending of MTBE and it has virtually disappeared from U.S. gasoline supply since May 2006 [as has methanol as a neat or synthesized fuel]. With the elimination of MTBE, the only significant use of methanol in U.S. fuel supply is its use in production of methyl ester biodiesel.

22. Frank S. Zeman & David W. Keith, *Carbon Neutral Hydrocarbons*, 366 Phil. Transaction Royal Soc'y A 3901, 3907 (2008), *available at* https://royalsocietypublishing.org/doi/10.1098/rsta.2008.0143; *see also* Olah et al., *supra* note 17, at 496; DOE Office of Energy Efficiency and Renewable Energy, *Alternative Fuels Data Center: Dimethyl Ether*, https://afdc.energy.gov/fuels/emerging_dme.html (last visited Mar. 25, 2021):

    > [DME] has several fuel properties that make it attractive for use in diesel engines. . . . The energy efficiency and power ratings of DME and diesel engines are virtually the same. . . . Because of its lack of carbon-to-carbon bonds, using DME as an alternative to diesel can virtually eliminate particulate emissions and potentially negate the need for costly diesel particulate filters.

    For a comparison analysis considering PtX pathways to transform electricity to chemicals via electrolysis and synthesis, see Vincent Dieterich et al., *Power-to-Liquid Via Synthesis of Methanol, DME, or Fischer-Tropsch-Fuels: A Review*, 13 Energy & Env't Sci. 3207 (2020), *available at* https://pubs.rsc.org/en/content/articlelanding/2020/EE/D0EE01187H#!divAbstract. *See also* Beuttler et al., *supra* note 6, at 4-5.
23. Olah et al., *supra* note 17, at 496.
24. *Id.*
25. 42 U.S.C. §7545, ELR Stat. CAA §211.
26. Hester, *supra* note 5, at 10425.
27. Olah et al., *supra* note 17, at 496.
28. *See* Michael Matzen & Yaşar Demirel, *Methanol and Dimethyl Ether From Renewable Hydrogen and Carbon Dioxide: Alternative Fuels Production and Life-Cycle Assessment*, 139 J. Cleaner Prod. 1068, 1068 (2016), *available at* https://core.ac.uk/download/pdf/188116801.pdf:

    > Results show that production of dimethyl ether impacts the environment more than methanol production. However, the combustion of methanol fuel evens out many of the emissions metrics compared to dimethyl ether. The largest environmental impact was found to be related to the fuel production stage for both fuels. Both biofuels were shown to be comparable to biomass-based gasification fuel production routes. Methanol and dimethyl ether from $CO_2$ hydrogenation were shown [to] outperform conventional petroleum-based fuels, reducing greenhouse gas emissions 82-86%, minimizing other criteria pollutants ([sulfur oxide] $SO_x$, $NO_x$, etc.) and reducing fossil fuel depletion by 82-91%.

    *See also* 42 U.S.C. §7545(k)(2)-(3) (concerning requirements and performance standards of gasoline/reformulated gasoline).
29. Trent Jacobs, *$CO_2$ EOR Could Be Industry's Key to a Sustainable Future or Its Biggest Missed Opportunity*, 72 J. Petroleum Tech. 17 (2020). This 1.1 teraton carbon budget is not an annual limit; rather, it reflects the cumulative allowable emissions to remain under 2ºC.
30. Ottmar Edenhofer et al., *Technical Summary*, *in* Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel

utilization, and storage (CCUS) capacity (which excludes naturally sourced $CO_2$ for enhanced oil recovery (EOR)) is currently just 39 megatons (Mt) per year, or 0.039 Gt.[31]

Current capacity to offset carbon output is growing by about 8% per year, but to actually start closing the gap and add meaningful time to the carbon budget, an additional 1 to 5 Gt each year is needed, requiring a doubling or tripling of current efforts.[32] In the absence of DAC-based CNHC production, this increased demand for DAC CCUS will require a tremendous volume of global storage capacity. Such permanent storage would be in the form of geologic sequestration in underground formations in either gaseous or solid (basaltic) form.[33] A broad "CNHC economy" (encompassing the proposed "methanol economy"), given the right economic incentives, would greatly complement global $CO_2$ sequestration efforts.

Over the past two decades, the United States has introduced increasingly stronger federal measures to incentivize the production of low-carbon synthetic fuels and to provide tax credits and other monetary incentives for non-EOR $CO_2$ utilization from DAC projects. The federal government (and certain states) have mandated the use of certain products and technologies to reduce emissions. They have also established performance standards that certain technologies must achieve, such as the federal Renewable Fuel Standard (RFS) (which requires that specified volumes of biofuels be blended into U.S. transportation fuels)[34] and California's Low Carbon Fuel Standard (LCFS).[35] Federal action in particular has made substantial progress, but it has not adequately kept pace with CCUS technologies that can produce CNHCs.

A recent equity research report by investment banking firm Goldman Sachs entitled "Carbonomics: The Green Engine of Economic Recovery" notes that past recessions, such as the 2008-2009 recession, did not significantly derail low-cost decarbonization technologies, but that higher-cost technologies with less regulatory support such as biofuels and carbon capture never recovered.[36] The authors of the report suggest that this past occurrence raises the risk of a "two-speed decarbonization re-emerging in the aftermath of COVID-19."[37] Although equity markets performed at an all-time high during the fourth quarter of 2020 and a new presidential administration was elected based in part on a robust climate action plan for federal decarbonization efforts, the risk of history repeating itself in the form of a widening chasm between bimodal cost distributions driven by market forces will require firm regulatory control to overcome.

This Article aims to provide policy guidance on how the U.S. federal government's regulatory framework can draw level to the technological advancements in this area. To expedite production of CNHCs, it proposes changes in two areas. First, it recommends that federal agencies amend existing regulations and guidelines to provide for stronger federal monetary incentives for DAC projects to make CNHC development more economically viable on a large scale.

Second, it recommends vital policy improvements to stimulate production of CNHCs by modifying key legislation (such as the RFS) to allow the federal government to approve broader fuel pathways beyond conventional biofuels. By taking a combined approach in these areas, these adaptations will allow for existing infrastructure utilization toward carbon-neutral fuel production and a resultant carbon-neutral transportation system until carbon-negative transportation technologies, sequestration schemes, and regulations are commercially viable, available, and well understood.

## I. Federal Incentives and Regulation for DAC Facility Development

Over the past decade, as technological advancements have progressed in the area of CCUS, the U.S. federal government has undertaken a variety of measures to help propel investment in research, development, and deployment of DAC facilities. These measures, however ambitious, have not kept pace with the increasingly pressing need for alternative energy and fuel sources in light of the increasing pace of climate change and the technological developments in these areas. Deployment of DAC facilities will cost in the billions of dollars,[38] and thus far the U.S. Congress has relied narrowly on federal tax credits under Internal Revenue Code (I.R.C.) §45Q to offset some of these costs to private developers. In the absence of more robust federal policies and programs, DAC facilities are currently unable to generate significant cash flow to provide for operating overhead nor significant return on investment.

As a result, developers have to turn to alternative fundraising schemes, such as tax-equity financing partnerships,

on Climate Change 45 (Ottmar Edenhofer et al. eds, Cambridge Univ. Press 2014), https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_technical-summary.pdf echnical-summary.pdf.

31. Jacobs, *supra* note 29.
32. *Id.*
33. See Beuttler et al., *supra* note 6, at 3, for more information about the CarbFix and CarbFix2 projects, which demonstrate that negative emissions via DAC with rapid mineralization is possible and replicable.
34. National Petroleum Council, *supra* note 3, at 30.
35. The LCFS is designed to decrease the carbon intensity (CI) of California's transportation fuel pool by assigning CI scores for various fuel types that are then compared to a declining CI benchmark each year.
36. Michele Della Vigna et al., Goldman Sachs, Carbonomics: The Green Engine of Economic Recovery 4 (2020), https://www.goldmansachs.com/insights/pages/gs-research/carbonomics-green-engine-of-economic-recovery-f/report.pdf.
37. *Id.*
38. Actual costs for projected full-scale DAC facilities are presently uncertain, as existing pilot plants do not mirror projected full-scale engineering design schematics, making price modeling incredibly difficult and highly variable based on thousands of input factors. Regarding full deployment-scale costs broadly, the author relies on representations made in direct conversations with executive leadership from DAC engineering companies and their investors. The costs of capture per ton/$CO_2$ annually, which largely drive the economics of full-scale design, are however increasingly surveyed both globally and domestically. *See* Yuki Ishimoto et al., Putting Costs of Direct Air Capture in Context (Forum for Climate Engineering Assessment Working Paper No. 002, 2017); *see also* Noah McQueen et al., *Cost Analysis of Direct Air Capture and Sequestration Coupled to Low-Carbon Thermal Energy in the United States*, 54 Env't Sci. & Tech. 7542 (2020), *available at* https://pubs.acs.org/doi/10.1021/acs.est.0c00476.

which, while productive, fail to provide much-needed direct stimulus. Enhancements to the current 45Q tax credit are necessary to stimulate private financing and scale deployment of CCUS projects, ranging between values of $60-$180/ton of captured $CO_2$ for qualified use.[39] Development stimuli also fail to take into account project longevity à la Solyndra,[40] the lessons of which can be summarized into a need for further government oversight during the early development phase and a need for better cradle-to-grave/gate life-cycle planning and partnership to regulate and secure adequate output demand and use.

By some estimates, renewable energy infrastructure is 1.5-3.0 times more capital-intensive than traditional energy developments per unit of energy produced, thus requiring an attractive regulatory framework and a low cost of capital.[41] Despite the higher capital intensity per unit of "cleaner" energy for transportation, this increased cost does not necessarily correlate to higher consumer costs, assuming the availability of highly available, well-regulated, low-cost financing and lower operating expenses (OPEX) (compared to traditional hydrocarbon production).[42] Done properly, DAC deployment can become a model for "pro-growth, pro-environment, public-private collaboration."[43]

This Article aims to provide policy guidance on how the federal government can better economically incentivize the development of both large-scale DAC facilities and ancillary CNHC refining facilities, as well as smaller-scale in situ facilities. Acknowledging the importance of the more general legal hurdles relating to deployment and operation, which include construction and infrastructure legal issues, legal consequences of operational impacts, and legal requirements for management of process wastes,[44] the analysis seeks to pivot toward development (i.e., capital expenditure (CAPEX)) policy and associated legal challenges.

Public law considerations involved in expediting DAC technologies are essential, and the pathway toward broad deployment must be laid out with a robust policy framework. At its core, such a framework deployed in the United States must "provide a clear statutory and regulatory endorsement of $CO_2$ removal as a desired goal of . . . environmental policy."[45] The Biden Administration's establishment of an international climate envoy—a new Cabinet-level position—as well as a domestic policy advisor on climate change is a step in the direction toward broader endorsement of DAC technologies and engaging in a unified decarbonization effort.

The next step in this process should entail a decision by the National Climate Task Force's Climate Innovation Working Group to endorse an Advanced Research Projects Agency-Climate (ARPA-C). The ARPA-C would exist in parallel to the ARPA-E (Energy), both under the umbrella of the U.S. Department of Energy (DOE). Among ARPA-C's top DAC-focused initiatives, the following four key areas should be of utmost priority: tax credits, public and private project financing, carbon pricing, and permitting barriers.

### *A. Tax Credits*

The present framework for incentivizing carbon oxide sequestration was born out of Congress' desire to enhance available tax credits for such activities. Congress originally enacted the Energy Improvement and Extension Act of 2008 to incentivize the reduction of carbon oxide emissions and support redeployment through efforts such as EOR by enacting a tax credit under 45Q. This production tax credit, commonly utilized in the renewable energy sector, is transactionally easier for investors, owners, and operators. It also provides "clear public benefit" in that payment is contingent upon performance of $CO_2$ emissions.[46]

The Bipartisan Budget Act (BBA) of 2018 substantially modified the existing 45Q credits for carbon oxide sequestration by expanding its application to the $CO_2$ DAC, and substantially increased the amount of the tax credit for captured $CO_2$. For facilities placed in service after the enactment of the BBA (no DAC facilities were in service prior to the enactment), the current 45Q legislation relating to DAC conveys a $50 tax credit per ton of $CO_2$ securely geologically sequestered and a $35 tax credit for $CO_2$ utilized in another qualified manner, with the credits for both increasing annually until the full value is reached in 2026.[47] A "qualified [DAC] facility" is defined as one that captures not less than 100,000 tons of $CO_2$ annually.[48]

H.R. 5883, introduced in the 116th Congress and presently awaiting re-introduction in the 117th Congress, sought to amend the I.R.C. to provide for marginally increased credit for carbon oxide sequestration for DAC facilities (from $50 per metric ton of qualified carbon oxide capture to $62.50), as well as a reduction in minimum carbon oxide capture volume (from 100,000 metric tons to not less than 50,000 metric tons) during the taxable year. This progression in regulation and the current proposed

39. Julio Friedman et al., Columbia University, Capturing Investment: Policy Design to Finance CCUS Projects in the U.S. Power Sector 6 (2020), https://www.energypolicy.columbia.edu/sites/default/files/file-uploads/CCUS-Finance_CGEP-Report_040220.pdf (advocating for prices in the $60-$110 range); *see also* John Larsen et al., Rhodium Group, Capturing Leadership: Policies for the US to Advance Direct Air Capture Technology (2019), https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/ (advocating for prices as high as $180/ton).
40. Solyndra was a startup manufacturer of unique solar panel cells that received a $535 million DOE development loan (the first of its kind) under the American Recovery and Reinvestment Act of 2009, as well as a $25.1 million tax break from California's Alternative Energy and Advanced Transportation Financing Authority. Due to inaccurately reported application information and changed market conditions, the company cost the federal government a $528 million loss following its bankruptcy. *See* Joe Stephens & Carol D. Leonnig, *Solyndra Scandal*, Wash. Post, Dec. 25, 2011, https://www.washingtonpost.com/politics/specialreports/solyndra-scandal/.
41. Della Vigna et al., *supra* note 36, at 3.
42. *Id.* at 13.
43. *Id.* at 3.
44. Hester, *supra* note 5, at 10414.
45. *Id.* at 10428.
46. Friedman et al., *supra* note 39, at 7.
47. Office of Fossil Energy, DOE, Internal Revenue Code Tax Fact Sheet (2019), https://www.energy.gov/sites/prod/files/2019/10/f67/Internal%20Revenue%20Code%20Tax%20Fact%20Sheet.pdf.
48. *Id.*

modifications are commendable, but nevertheless remain insufficient to properly incentivize rapid DAC development and deployment. A re-introduction should account for this greater incentivization need.

In their article "The Role of Direct Air Capture in Mitigation of Anthropogenic Greenhouse Gas Emissions," executives from Swiss DAC firm Climeworks note that "various climate scenarios predict negative emissions at gigaton scale by mid-century . . . to reach a mean CDR pathway of around 6 gigatons of CDR by 2050 from 2019 onwards, CDR would require an annual growth rate of over 55%."[49] The authors note that delaying scale-up to 2025 would require a sustained growth of 80% per year, while scale-up starting in 2030 (which is when most CDR policies are currently recommended to commence) would require an approximate yearly doubling of CDR capacity. Growth trends of this magnitude would be incredibly difficult to achieve, and thus the authors determine "that it would therefore be vital to start scaling earlier."[50]

A fundamental policy consideration that is presently overlooked is that the determinative figures need to better balance ambitious goals with present economics of scale. The 45Q credits at present do not account for the high up-front CAPEX costs that necessarily exist in such a nascent technological field where large-scale development is the primary goal. Instead of using comprehensive lifecycle determinations of tax credit qualifications designed to allow current negative emissions technologies (NETs) to take advantage of the tax credits by recognizing the high up-front technology costs and low capacity volume (which will inevitably fall over time as new technologies evolve), the current tax credits provide an inadequate lifecycle accounting.

This significantly increases the financial risks involved in deployment and operation of such infrastructure. With a present minimum eligibility of 100,000 tons of CDR per year (and even a proposed 50,000 tons), DAC facilities of this size "would very likely exceed current market capitalization of all leading DAC companies and put the ones that decide to try [to scale to the 100,000 ton annual CDR goal] at considerable risk of failure."[51] In addition, the authors note that the revenue stream that the present 45Q establishes at up to $50 (and even a proposed $62.50) per ton of $CO_2$ is insufficient to cover the costs of atmospheric CDR with current technologies.[52]

H.R. 5883 is a good step in the right direction toward recognizing this conundrum; nevertheless, CDR policies—including and beyond 45Q—need to accommodate this fact by allowing for even lower removal thresholds at higher prices while implementing market demand mechanisms to drive the pace of technological innovation. In order to meet the growing demand of CNHC fuel production and carbon sequestration credits, installed capacity will increase and new efficiencies in design will allow for companies to require less and less support. This inverse relationship is what is missing. The absolute amount of financing required to fund initially high-priced CDR technology is negligible compared to the required gigaton-scale carbon removal.[53]

A 2019 report by independent research firm Rhodium Group highlighted some of the necessary policy changes involving the aforementioned inadequately priced tax credits. In outlining a comprehensive industrial strategy to stimulate DAC technological demand, the report's authors appropriately call for extending the commence-construction deadline for DAC eligibility to the end of 2030; extending the credit payout period from 12 years to 30 years; increasing the value of the credit for geologic storage from $50 to $180 per ton; and lowering the minimum capture thresholds from 100,000 to 10,000 tons per year.[54] These changes will allow the first wave of commercial DAC plants to break even, particularly if they also were to incorporate revenue from California's LCFS.

The report's authors note that "the total annual cost to the government in 2031 would be just $1.5 billion to support nine-million tons of DAC capacity, roughly half the current annual cost of solar photovoltaic tax credits."[55] This proposal is the most aggressive proposal to date that also accurately reflects the market dynamics required to achieve both short- and long-term success in decarbonization efforts of this kind. The reduced volumetric requirements would also create an opening for R&D into smaller-scale DAC PtX units that might play a role in future technological advancements.[56]

A technology and cost analog to DAC is the area of solar and wind energy. Between 2010 and 2019, the cost of solar power generation fell 85% and the cost of wind power generation fell 49%; the costs of both continue to decline.[57] A recent analysis by Bloomberg New Energy Finance shows that the global benchmark levelized cost of electricity (LCOE) from utility-scale wind and solar power generation fell 9% and 4% respectively from late 2019 to early 2020, while benchmark LCOE for battery storage likewise declined to about one-half of what it was in mid-2018.[58] By mid-2020, renewable energy power was cheaper than fossil fuels in two-thirds of the world.[59]

This comparison to DAC in other renewable power-generation sectors is very important, as it clearly demonstrates the capacity for nascent utility-scale technologies to very

49. Beuttler et al., *supra* note 6, at 5-6.
50. *Id.* at 6.
51. *Id.*
52. *Id.* (noting that these calculations apply to both Climeworks and Carbon Engineering—presently the two foremost companies worldwide in the DAC/CDR space).
53. *Id.*
54. Larsen et al., *supra* note 39.
55. *Id.*
56. Such as in areas constrained by land use availability, or for niche uses, such as combined DAC and fuel synthesis/production co-located with transportation service stations.
57. Sarah Golden, *What Engie's Tax Equity Deal Tells Us About Financing Renewables*, GreenBiz, May 1, 2020, https://www.greenbiz.com/article/what-engies-tax-equity-deal-tells-us-about-financing-renewables.
58. *Scale-Up of Solar and Wind Puts Existing Coal, Gas at Risk*, BloombergNEF, Apr. 28, 2020, https://about.bnef.com/blog/scale-up-of-solar-and-wind-puts-existing-coal-gas-at-risk/.
59. Golden, *supra* note 57.

quickly gain cost efficiencies and capacity. Much of this is due to the long-term outlook of the output purchasing entities, who can insert stability into the output purchase agreements to give developers a certain return on investment over time.[60] If the federal government can establish policies that go beyond tax credits to take into consideration both CAPEX and OPEX with an aim of supporting the DAC sector in a comprehensive way (as opposed to merely offsetting investment costs), then DAC will likely enjoy the output stability and resultant cost and technology efficiencies that wind and solar benefit from.

Avoiding a two-speed decarbonization will be essential to the longevity of DAC as a viable CDR method and potential fuel-generation source. The European Renewable Energy Directive 2 (RED2) demonstrates this concept clearly. RED2 allows for atmospheric $CO_2$ as a feedstock for synthetic fuels; however, the regulation also allows for point source $CO_2$ capture from fossil fuel-based flue gas, which is sourced at much lower cost (due to the higher $CO_2$ concentration). In the marketplace, regulations like RED2 place an overall incentive on point source $CO_2$ capture rather than ambient DAC $CO_2$ and therefore fail to trigger much needed CDR scale-up, leading to a two-speed decarbonization that disincentivizes DAC technological development and mass deployment.[61]

A two-speed decarbonization may also arise from fiscal stimulus competition of CDR/DAC technologies with existing, at-scale renewable solar, wind, and biofuel projects. In Goldman Sachs' "Carbonomics" equity research report, the authors note that this inherent conflict "may ultimately delay the technological breakthroughs necessary to flatten the de-carbonisation cost curve and achieve cost-efficient net zero carbon."[62] In the absence of robust regulation and long-term, government-backed purchase programs, high deployment costs will almost certainly delay the development of carbon markets, and in turn will "delay R&D and pilot projects that could lead to technological breakthroughs for the high end of the de-carbonisation cost curve."[63] While two-speed decarbonization is nevertheless decarbonization, it may ultimately inhibit the acceleration toward an eventual net-negative scenario.

The Internal Revenue Service (IRS) published a notice of proposed rulemaking (NPRM) on June 2, 2020, calling for public comments in response to proposed regulations under I.R.C. §45Q.[64] More than 55 public comments were submitted in response, covering a range of issues and concerns. The most pressing of these comments that concern DAC and potential decarbonization of transportation networks address the life-cycle assessment (LCA) methodology, seek to define qualified utilization purposes, seek to modify "fuel" requirements, and seek to make credit determination more streamlined and transparent.

LCA is a well-established method that takes the entire life cycle of an extracted compound into account, from the extraction of raw materials to the final use or disposal (thus the terms "cradle-to-gate" and "cradle-to-grave"). LCA International Organization for Standardization (ISO)[65] standards have recently been adapted for $CO_2$ utilization in LCA guidelines developed by the Global $CO_2$ Initiative and DOE's National Energy Technology Laboratory. In a recent report addressing the carbon footprint of $CO_2$ as a feedstock, the authors note that "carbon footprints . . . range from positive—implying that $CO_2$ capture is harmful to the climate—to negative which suggests benefits" and therefore call for a more consistent determination of the carbon feedstock $CO_2$, as these differences "can substantially impact the selection of environmentally beneficial $CO_2$ sources in industry and policy-making, and even the perception of CCU in general."[66]

The Rhodium Group's report also notes that accounting for appropriate LCA methodologies is important for identifying the total effect of carbon footprint reduction for purposes of regulatory planning.[67] The report also splits the LCA for a DAC fuel-generation output scenario (as opposed to a sequestration output scenario), and illustrates that $CO_2$ from fossil fuel-based point sources does not have the same life-cycle $CO_2$ reduction effect (unless the $CO_2$ in the flue gas stream comes from biomass), "as fossil $CO_2$ in essence is reused once more in the synthetic fuel, before it is released back into the atmosphere."[68]

One of the most significant public comment letters that is DAC-industry specific was submitted jointly by the executives of Carbon Engineering, CarbonPoint Solutions, Core Energy, Cornerpost $CO_2$, and Perdure Petroleum, in which the authors acknowledge that "the statute in Section 45Q establishes the beginning boundary" of LCA for purposes of the 45Q credit, and that 45Q utilization LCA "only starts after the qualified carbon oxide is captured."[69] The letter clarifies that one of the purposes of the LCA analysis "is to ensure that a utilization process does not emit more carbon oxide than was captured . . . [and] to preclude a claim of 45Q credits when more carbon oxide is emitted through the utilization process than the amount

60. *Id.*
61. Larsen et al., *supra* note 39.
62. Della Vigna et al., *supra* note 36, at 3-4 (the report's cost curve shows that ~50% of global $CO_2$ emissions need a carbon price in excess of $100/ton to be decarbonized with current technologies).
63. *Id.* (noting further that only 16% of total global emissions are currently taxed and the average global carbon price is $3/ton—"a long way from the price required to foster broad clean tech innovation").
64. Credit for Carbon Oxide Sequestration; Correction, 85 Fed. Reg. 39113 (June 30, 2020) (to be codified at 26 C.F.R. pt. 1), *available at* https://www.govinfo.gov/content/pkg/FR-2020-06-30/pdf/2020-13705.pdf.
65. ISO creates global commercial product standards, identified by their ISO number.
66. Leonard Jan Müller et al., *The Carbon Footprint of the Carbon Feedstock $CO_2$*, 9 Energy & Env't Sci. 2979, 2980 (2020), *available at* https://pubs.rsc.org/en/content/articlelanding/2020/EE/D0EE01530J#!divAbstract.
67. Larsen et al., *supra* note 39.
68. *Id.*
69. Letter from Presidents/Chief Executive Officers of Carbon Engineering et al. cmt. 39 (Aug. 1, 2020), Notice of Proposed Rulemaking on Section 45Q Credit for Carbon Oxide Sequestration (Docket IRS-2020-0013) (in response to IRS NPRM for the Credit for Carbon Oxide Sequestration, 85 Fed. Reg. 34050 (June 2, 2020)) (on file with Baker Botts L.L.P. at https://www.bakerbotts.com/thought-leadership/publications/2020/august/finding-tool-for-public-comment-letters-carbon-capture-tax-credit-proposed-regulations-section-45q).

of qualified carbon oxide captured in the first place."[70] The letter goes on to state that the authors support developing clear and simplified criteria "for utilization process approvals, and for approval in the final regulations of fuels as a commercial market and product for a utilization process."[71]

Other pivotal determinations to proposed 45Q modifications that are essential to the longevity of the industry concern utilization, commercial product/market determinations, and §45Q(f)(5)(A)(iii) determinations. Section 45Q(f)(5)(A) defines "utilization of qualified carbon oxide" as one of three different processes: (1) a photosynthesis/chemosynthesis process, (2) a chemical conversion process, and (3) a process where the qualified carbon oxide is used for any other purpose for which a commercial market exists (other than $CO_2$-EOR/EGR[72]) to be determined by the secretary.[73] The third process (the "commercial product provision") arguably must take into consideration that "commercial market" may refer both to a market for a product (e.g., DAC-based $CO_2$ synthesized fuels) or a service (e.g., DAC and $CO_2$ geologic sequestration in a carbon budget trading market).

The LCA required for each utilization process will differ, but both should be provided for in legislation to qualify for a 45Q credit. The authors of the letter myopically support final regulations, stating that carbon oxide's use as a service should not qualify for a 45Q credit and that "a product must be the end result of any approved utilization process that uses up or converts the qualified carbon oxide."[74] This overlooks the dual potential of DAC to provide for both CNHC fuels as a product toward a carbon-neutral fuel economy and sequestration as a service (in a government-mandated carbon management regime).

The letter's authors, focusing on product-based utilization, rightfully determine that the I.R.C. must better explain the criteria taxpayers must satisfy to obtain a §45Q(f)(5)(A)(iii) determination. A determination must be sufficiently broad to include "both (a) processes where the qualified carbon oxide is placed into the product, and (b) processes where the qualified carbon oxide loses its chemical identity and is used up in some way in the process of making the product."[75] The intent of this request, pivotal to the long-term success of DAC $CO_2$ as a product, is to establish that, by regulation, there should be an express determination of "fuels" as being an example of a qualified commercial market.

Fuels have a commercial market in transportation and energy production and can be produced through $CO_2$ synthesis through a process that uses captured carbon oxide, including qualified carbon oxide. Therefore, it is essential that Congress' intent in leaving "commercial market" ambiguous does not prevent otherwise qualified companies appropriately seeking to claim 45Q credits from claiming credits, even when certain end products may not yet compete in the open market (e.g., due to lack of infrastructure, fuel utilization methods in transportation, undeveloped markets or consumer bases, etc.), and may not be "commercially" profitable at the time of the request.

### B. *Financing*

Funding large-scale DAC projects has thus far been difficult, as the extent of research and design has been limited to presently only a few pilot demonstration projects worldwide. Opening the doors to broader capital inflows would allow for more rapid deployment of technological and economic feasibility studies and scale-up of proven designs to sooner address climate change goals. Avenues of financing vary widely, from a proposal by the National Petroleum Council (NPC) calling on Congress to expand access to I.R.C. §48 tax credits[76] to all CCUS projects,[77] to greater third-party tax-equity financing incentives through investment tax credits (ITCs), to modifying the existing 45Q tax credit and turning it permanently into a "direct pay" incentive to monetize the tax credit without tax equity investors,[78] to DOE's ARPA-E and proposed ARPA-C programs to rapidly grow the industry.

Presently, the most widely available funding mechanism for DAC technologies that need CAPEX inflow and have tax credits to trade for up-front cash would be to conduct tax-equity financing through a partnership flip. Partnership flips are a common tax-equity financing structure in renewable energy markets,[79] allowing technologies to mature in production capability until which point companies can swap with the investor(s) to reclaim the credits once they begin to become financially self-sustaining for OPEX needs. The tax equity investor would in turn be able to benefit by obtaining production or ITCs, as well as depreciation credit, interest deductions, and operating income deductions.[80]

During the initial phase of the project, the tax equity investor will receive most of the tax benefits, as well as the income or loss (often the share is 99%), while the developer retains a small allocation of tax benefits and income (profit

70. *Id.*
71. *Id.*
72. Enhanced gas recovery.
73. 26 U.S.C. §45Q (as of Dec. 7, 2020).
74. Letter from Presidents/Chief Executive Officers of Carbon Engineering et al., *supra* note 69.
75. *Id.*
76. *See* H.R. 5165, 116th Cong. (2019) (provides tax credits to advanced coal projects and related emissions sequestration).
77. Letter from Greg Armstrong, Chair, NPC, to Dan Brouillette, Secretary of Energy, DOE (Dec. 12, 2019) (on file with NPC) (effectively expanding current policies to a level of ~$90/ton of $CO_2$ in the "expansion phase" to provide incentive for further economic investment and then to $110/ton in the "at-scale" phase, while simultaneously increasing the level of R&D funding for CCUS technologies to $15 billion over the next 10 years, "with a significant amount directed to less mature and emerging technologies that offer the greatest potential for a step change in performance and cost reduction").
78. Deepika Nagabhushan, *The Status of Carbon Capture Projects in the U.S. (And What They Need to Break Ground)*, Clean Air Task Force, Apr. 22, 2020, https://www.catf.us/2020/04/the-status-of-carbon-capture-projects-in-the-u-s-and-what-they-need-to-break-ground/.
79. Mark P. Keightley et al., Congressional Research Service, Tax Equity Financing: An Introduction and Policy Considerations 9 (2019), https://www.everycrsreport.com/files/20190417_R45693_01142998298c9e6feec6aba5c48b6ff238a58886.pdf.
80. *Id.*

or loss).[81] Once the tax equity investor has achieved a targeted internal rate of return, the partners' interests in the project company will flip, with the developer now receiving most of the tax benefits and income (profit or loss) associated with the project (typically 95%, leaving the tax equity investor with 5%).[82] In certain circumstances, a profitable developer may also seek to buy out the tax equity investor, such that the tax equity investor no longer owns any part of the project.

Tax equity generally provides a portion of a project's capital needs—somewhere from 30% to 60%, depending on the specifics of the project.[83] However, DAC tax-equity financing is likely to track more closely with other renewable energy projects, where tax equity is generally more expensive than other sources of debt financing. In the absence of appropriately sized direct governmental grants or awards,[84] the IRS is effectively mandating the use of this tax financing structure for DAC facilities, which cannot otherwise rely on existing economics and regulations to achieve full-scale deployment.

One major concern for future renewables, NETs, and DAC technology funding in regard to third-party tax-equity financing arose when the Tax Cut and Jobs Act was signed into law in 2017, which lowered the corporate tax rate from 35% to 21%. These lower corporate tax rates "mean[t] a reduced appetite for tax credits generally, which create[d] a serious challenge for renewable energy project financing," given that tax equity makes such a large share of the total financing for most of these projects.[85] In the wake of the passage of the Tax Cut and Jobs Act, Bloomberg reported that $3 billion worth of tax equity deals were on hold.[86] On March 31, 2021, President Joe Biden formally proposed a $2 trillion package of infrastructure spending, which among other proposals included raising the corporate tax rate to 28% in an effort to re-ignite these deals.

Calling for an alternative format to monetize the carbon capture tax credit without tax equity investors, the Clean Air Task Force (CATF) called for modifications to the existing 45Q tax credit to turn it permanently into a "direct pay" incentive.[87] A direct pay incentive, CATF argued, would act as a tax reimbursement, helping to ensure the taxpayer could monetize the full value of the credit and access general investing and lending markets, instead of relying on the specialized and shrunken tax equity investment market.[88]

In line with providing better access to lending markets for these NET companies, another possible financing mechanism could be to obtain debt financing through direct loans and guaranties of up to $1 billion for tenors as long as 25 years through the U.S. International Development Finance Corporation (DFC). Targeting growth, innovation, and inclusion (i.e., environmental justice) initiatives, the DFC's investment goals would sync well with DAC deployment goals. As the major DAC companies presently in the market are not American, obtaining support from the DFC would require U.S. ownership of at least 25% of the equity in the project, with possible exceptions to equity requirement in cases where U.S. brand name franchisors, operators, or contractors are significantly involved in the project.[89] Alternatively, federal transition bonds linked with the United Nations Sustainable Development Goals would support debt financing.

The latest legislation pertaining to DAC financial incentivization in the newly formed 117th Congress includes H.R. 1062 (Accelerating Carbon Capture and Extending Secure Storage Through 45Q (ACCESS 45Q) Act), H.R. 1761, S. 985, and S. 986. Collectively, these bills—all introduced in the first few months of the latest Congress—constitute a launching point for a re-invigoration of the §§45Q and 48C ITCs. H.R. 1062 calls for an extension of the tax credit for carbon oxide sequestration through 2035, and allows taxpayers an election to receive payments in lieu of the credit.[90] This direct-pay incentive has been highly sought-after by developers seeking to finance large-scale projects without needing to enter into equity swaps to monetize their credits.

H.R. 1761 calls for an amendment to Title XVII of the Energy Policy Act of 2005 relating to the eligibility for loan guarantees for carbon capture, utilization, and storage projects (and for other purposes).[91] Sister bills S. 985 and S. 986 likewise focus on the I.R.C.'s tax credits and mirror in large part their U.S. House of Representatives counterparts above. S. 985[92] calls for an amendment to the I.R.C. to provide direct payments of the renewable electricity production credit, the energy credit, and the carbon oxide sequestration credit, whereas S. 986[93] calls for a five-year extension of the carbon oxide sequestration credit (and for other purposes). These bills largely mirror their counterparts that expired in the 116th Congress, yet there are a few notable bills that have yet to be re-introduced into the 117th Congress as of this writing.

From the 116th Congress, H.R. 3607 sought to amend the Energy Policy Act of 2005 to direct DOE to carry out

81. *Id.*
82. *Id.*
83. *Id.*
84. *See* H.R. 3607, 116th Cong. §969G(i)(1) (2019) (air capture technology prize) (referencing the DOE/ARPA OPEN grant program).
85. CohnReznick LLC/CohnReznick Capital Market Securities LLC, 2019 Trends in Renewable Energy Financing (2019), https://www.cohnreznick.com/-/media/resources/2019_trends_in_utility_renewable_energy_financing.pdfnds_in_utility_renewable_energy_financing.pdf.
86. Brian Eckhouse & Chris Martin, *How Trump's Tax Plan Made It Harder to Finance Renewables*, Bloomberg, Jan. 12, 2018, https://www.bloomberg.com/news/articles/2018-01-12/seeking-renewables-financing-trump-s-tax-plan-made-it-harder.
87. Nagabhushan, *supra* note 78.
88. *Id.*
89. DFC, OPIC Handbook 12 (2019), https://www.dfc.gov/sites/default/files/2019-08/OPIC_Handbook.pdf.
90. H.R. 1062, 117th Cong. (2021) (referred to House Committee on Ways and Means).
91. H.R. 1761, 117th Cong. (2021) (referred to Committee on Energy and Commerce, and Committee on Science, Space, and Technology).
92. S. 985, 117th Cong. (2021) (referred to Committee on Finance).
93. S. 986, 117th Cong. (2021) (referred to Committee on Finance).

atmospheric, large-scale CCUS R&D programs, would have required DOE to submit a report to Congress on CCUS activities, and would have required DOE to establish air capture technology prizes provided under a competition as well as grants for centers that test DAC and storage technologies.[94] Similarly, S. 1201 sought to amend the Energy Policy Act of 2005 to direct DOE to carry out an expanded program of research, development, and demonstration for CCUS and to authorize DOE programs regarding large-scale removal of atmospheric $CO_2$ (including DAC technologies).[95] Lastly, H.R. 5165 sought to renew and expand the §48C ITC for investments in building new manufacturing facilities or expanding existing facilities to produce clean energy technologies.[96]

The final iteration of H.R. 5165 called for a $2.5 billion annual credit limitation from 2020-2024. The 48C credit supports manufacturing facilities of wind and solar power technologies, electric vehicles, carbon capture, smart grid technologies, and renewable fuels, among others. The planned growth of these industries in the coming years and decades will require a substantially greater dollar value investment and increased year-on-year funding to meet our targeted climate intervention objectives, particularly as new technologies emerge, and existing ones mature.[97]

A re-introduction of the aforementioned bills—updated appropriately—into the 117th Congress is an essential next step toward broadening the financial pathways for DAC technologies and feedstock output utilization. Reintroduction would also benefit from a re-consideration of the primary constituent base, as several of these bills reflected a legislative intent to benefit the fossil fuel industry, not the nascent decarbonization industry. For example, H.R. 3607's "authorization of appropriations" under §961, authorized "to be appropriated to the Secretary for activities under this section regarding carbon utilization (1) $25,000,000 for fiscal year 2020 . . . [up to] (5) $30,387,656 for fiscal year 2024," representing an appropriation in 2020 reflecting .0005% of the U.S. annual budget (which in 2020 was $4.79 trillion) for a climate crisis that portends economic loss far beyond this meager appropriated R&D amount.

However, the proposed acts both paved the way for greater development of CDR and DAC-fuel synthesis programs. Notably, H.R. 3607 called for

> a program of research, development, and demonstration for carbon utilization . . . [that] shall identify and evaluate novel uses for carbon, including the conversion of carbon oxides, in a manner that, on a full life-cycle basis, achieves a permanent reduction in, or avoidance of a net increase in carbon dioxide in the atmosphere, for use in commercial and industrial products, such as . . . fuels.[98]

Additionally, H.R. 3607 in §11 (Carbon Removal) sought to further amend Title IX of the Energy Policy Act of 2005[99] by adding language calling for the establishment of a research, development, and demonstration program to remove $CO_2$ from the atmosphere on a large scale that shall identify and develop carbon removal technologies and strategies that consider (among various considerations) commercial viability and economic co-benefits.

The bill took the bold step of seeking to establish an "air capture technology prize" to support carbon removal pilot and demonstration projects with their own declining appropriations schedule, beginning with $75,000,000 for fiscal year 2020 ($15,000,000 of which would apply to the air capture technology prize). In S. 1201 §969 (Carbon Utilization Program), the proposed act called for the secretary to (1) "establish a program of research, development, and demonstration for carbon utilization," and to (2) "identify and assess novel uses for carbon, including the conversion of carbon oxides for commercial and industrial products, such as . . . (D) fuels."[100] While similar to H.R. 3607 §963A, the overall focus of S. 1201 was to enhance fossil fuel carbon technology, not to fund decarbonization technologies directly.

Ideally, Congress would revive, combine, and accelerate components of currently proposed acts in the 117th Congress with expired legislation remodeled from the 116th Congress and with existing laws. New legislation must be designed exclusively to promote decarbonization efforts, taking into consideration the pressing need for higher appropriation amounts, larger prize incentives, more robust R&D support, greater assurances of feedstock and/or product output demand, and reduced legal liability and/or government indemnifications for climate effects of large-scale $CO_2$ removal.

Another high-impact area is DOE's ARPA-E program, and the proposed ARPA-C program. The ARPA-E, created in 2007 under the Bush Administration and funded in 2009 under the Obama Administration, focuses on "transformational low-carbon energy technologies."[101] At the outset of 2021, ARPA-E made its latest $100 million funding opportunity announcement, targeted at specific technical areas both inside and outside of the current agency portfolio. President Biden's proposed ARPA-C, expected to take on a larger suite of climate-related tools,[102] will require an act of Congress to create the new agency, and appears to have significant research overlap with ARPA-E.

94. H.R. 3607, 116th Cong. (2019) (referred to Committee on Science, Space, and Technology).
95. S. 1201, 116th Cong. (2019) (referred to Committee on Energy and Natural Resources).
96. H.R. 5165, 116th Cong. (2019) (referred to Committee on Ways and Means).
97. *See* Jackie Toth, *Manufacturing the Future of Clean Energy With 48C*, Third Way, Dec. 18, 2020, https://www.thirdway.org/memo/manufacturing-the-future-of-clean-energy-with-48c (calling on Congress to make at least $3 billion available in new 48C credits in each of the next five tax years to increase the number of manufacturers throughout the country that can benefit from the program).
98. H.R. 3607, 116th Cong. §963A(a)(2)(D) (2019).
99. 42 U.S.C. §§16291 et seq.
100. S. 1201, 116th Cong. §969(a) (2019).
101. James Temple, *Here's Biden's Plan to Reboot Climate Innovation*, MIT Tech. Rev., Feb. 11, 2021, https://www.technologyreview.com/2021/02/11/1018134/heres-bidens-plan-to-reboot-climate-innovation/.
102. *Id.*

Given this lack of clear delineation between the two, the Biden Administration should encourage DOE to more narrowly tailor the scope of each agency to better increase the odds of passing ARPA-C through Congress. The failure to pass ARPA-C would likely result in an expanded ARPA-E mandate, which could "maroon those clean technologies not directly related to energy, perhaps including carbon sequestration."[103] Ideally, Congress will pass President Biden's proposed $2 trillion climate investment plan, narrowly tailor ARPA-E and -C to better distinguish the two and guarantee broader funding pathways overall, and ensure a stronger mandate within each for funding DAC facilities and renewable fuel programs.

## *C. Legal Permitting*

In the world of environmental law, legal permitting is the paramount hurdle for any proposed course of action that could have an effect on the natural world. In terms of expediting NETs into operation, Prof. Tracey Hester writes, "regulatory agencies and policymakers, especially EPA and state agencies with delegated authority to issue environmental permits, can explore whether to reduce permitting barriers or environmental review disincentives for laboratory research or limited field testing of NETs."[104] In his ELR article "Legal Pathways to Negative Emissions Technologies and Direct Air Capture of Greenhouse Gases," he outlines five legal-oriented angles to expedite NET deployment:

1) EPA could extend its current conditional Resource Conservation and Recovery Act (RCRA)105 and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)106 exemption for $CO_2$ captured from industrial operations for geologic storage to also include $CO_2$ captured from the ambient atmosphere by DAC operations.
2) For broader deployment or implementation, EPA and state environmental agencies can adopt (1) standardized approval and review procedures for NETs that use common procedures or similar physical designs, and (2) general permits for NETs that will likely have either small or predictable and controlled impacts to the environment.
3) The president could issue an Executive Order directing expedited federal review of NET projects and activities.
4) Congress could adopt legislation to provide favorable waivers or reduced environmental reviews of NET projects similar to the limited federal waiver from state permitting requirements on the same model used for CERCLA.
5) More controversially, Congress and state legislatures and agencies can reduce barriers to NETs posed by land acquisition or authorization requirements by utilizing their power to authorize condemnation of property needed for these projects and with appropriate oversight and protective limitations, Congress or state legislatures could also extend that condemnation power to private parties who engage in industrial-scale NET operations authorized by state or federal permits or certificates of convenience.[107]

Concerning DAC and fuel production output, among these legal permitting options, the need for list item (1)—EPA to extend exemptions to include $CO_2$ captured from the ambient atmosphere by DAC operations—would provide greater investor and operator clarity in (obtaining) financing while also giving assurances of federal preemption and immunity for actions in this respect. Additionally, the potential of list item (3)—the president issuing an Executive Order directing expedited federal holistic feasibility assessments[108] and reviews of NET projects and activities—seems highly likely, given the representations made by the current Biden Administration, and would be well received by the DAC industry as a means of accelerating utility-scale market operations entry.

## *D. Carbon Pricing*

Professor Hester notes that "the most powerful concept that could accelerate private-sector NET research and deployment would be the imposition of a carbon tax or other pricing mechanism that would expressly allow NET operators to obtain a financial return on the $CO_2$ they capture from the atmosphere."[109] If the federal government should fail to adequately address the needs of the DAC industry in the abovementioned categories, states themselves may seek to follow the lead of California—and to a lesser extent that of New York—in establishing either a comprehensive carbon credit trading market or simply a specific carbon emission tax. This laissez-faire approach would function at the whim of market forces, allocating resources where investors identify the most gains.

Problems with this methodology arise quickly, as it reduces the largest possible incentives for investors to migrate their assets toward such nascent technologies in the absence of mature technologies and adequate demonstrations of such—which themselves require enormous investment. Further,

103. *What Will Clean Energy Look Like in the Biden Administration?*, Perkins Coie, Dec. 16, 2020, https://www.jdsupra.com/legalnews/what-will-clean-energy-look-like-in-the-34852/.
104. Hester, *supra* note 5, at 10429.
105. 42 U.S.C. §§6901-6992k, ELR Stat. RCRA §§1001-11011.
106. 42 U.S.C. §§9601-9675, ELR Stat. CERCLA §§101-405.
107. *Id.*
108. *See* Terese Thoni et al., *Deployment of Negative Emissions Technologies at the National Level: A Need for Holistic Feasibility Assessments*, 2 Frontiers Climate 2 (2020), *available at* https://doi.org/10.3389/fclim.2020.590305 (examining the potential contribution of NETs to meet global emission goals through 17 Long-Term Low Greenhouse Gas Emission Development Strategies in the context of available NETs feasibility assessments).
109. Hester, *supra* note 5, at 10430.

> the use of NET projects to generate tradable carbon credits . . . would likely prove controversial in light of concerns over verifying the validity of the traded credits and unexpected side effects created by prior $CO_2$ trading systems . . . [or by] a large number of credits generated by commercial NET ventures [that] might overwhelm other policy, ethical, and social goals.[110]

California's LCFS and New York's Climate Leadership and Community Protection Act (Climate Act)[111] both set excellent examples of state leadership in areas of federal inaction, and each provides model frameworks and lessons for both the federal government and other states to follow. These states show that regulation and legislation are needed in consort, propelling the market with both carrots and sticks.

New York's Climate Act has identified a "high technology availability" pathway relying on a diverse portfolio of GHG mitigation options, including "high levels of efficiency and end-use electrification, as well as contributions from measures not yet widely commercialized, such as advanced biofuels, carbon capture and storage (CCS), and bioenergy with carbon capture and storage (BECCS)."[112] The state's report concludes with six proposed areas of future research, the final area being "to improve assessment of carbon capture and storage potential within the state, especially focusing on geographic opportunities for carbon storage and utilization."[113] New York would do well to construe "carbon capture," "carbon storage," and "utilization" in their broadest senses, so as to increase their likelihood of meeting their high technology pathway goals by 2030 and beyond, while simultaneously supporting a market for investment that could spur greater technological growth.

The Biden Administration, recognizing the power of carbon markets to better incentivize NETs, should capitalize on its majority in both the House and the U.S. Senate and follow these states' lead by prioritizing the alignment of federal climate goals and federal capital allocation.[114] By establishing a federal carbon cap-and-trade system, akin to that passed in the House as the American Clean Energy and Security Act of 2009, such a program could firmly incentivize rapid carbon removal through carbon pricing and pure market forces. This program could also include elements from the proposed 2009 Carbon Limits and Energy for America's Renewal (CLEAR) Act, which would have capped $CO_2$ emissions and allowed for limited emissions trading as well as rebating the revenue back to the public. By rebating the revenue from a federal cap-and-trade program back into federal climate action-earmarked funds, this in turn could supplement the available financing resources discussed above.

Such a federal mandate was recently put to the test in Canada, where many conservative oil-producing provinces challenged the constitutionality of the federal government's imposition of carbon taxes. Citing Parliament's power to legislate on matters related to "peace, order and good government," the Supreme Court in a 6-3 ruling held that fighting climate change by reducing greenhouse gas emissions was a matter of "national concern" and "critical to our response to an existential threat to human life in Canada and around the world," and was thus protected under their Constitution.[115] It is time for the United States to follow suit, using the example Canada has set for the world.

## II. Federal Incentives and Regulation for DAC Feedstock Output and Adaptation

At present, DAC technologies have the capacity to capture, isolate, and compress $CO_2$ for either geologic sequestration, non-geologic storage, or pipeline transportation for various downstream uses. Research going back more than a decade has demonstrated the capability of $CO_2$ to act as a feedstock for synthetic fuels, and promising new R&D from DAC firms demonstrates the capacity of DAC facilities to provide adequate $CO_2$ feedstock for CNHC production for broad fuel use, and potentially to combine the capture and synthesis process in situ. This process, if rapidly deployable and scalable, would very quickly enable a drive toward a carbon-neutral transportation cycle, eliminating the need for present production volume of fossil/organic hydrocarbons. Until such point that the market for hydrocarbon fuels is entirely eclipsed by alternative energy sources and technologies, CNHCs provide the best climate-friendly solution.

More than ever in human history, there is a pressing need to improve domestic federal incentives for production of CNHCs. Noting that the continuous rise of atmospheric $CO_2$ levels represents one of the most critical environmental issues of the 21st century, the authors of a 2014 report on advances in catalytic hydrogenation of $CO_2$ argue that the rise "imposes urgent measures for a major cut of $CO_2$ emissions by an extensive recycle to valuable chemicals and fuels, like methanol (MOH) and dimethylether (DME)."[116] To incentivize such intensive recycling, a strong approach would target a modification of the existing RFS and support development of either statewide or federal carbon-capture programs to allow EPA to approve broader fuel pathways beyond conventional biofuels.

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110. *Id.* at 10430-31.
111. Energy and Environmental Economics, Inc., Pathways to Deep Decarbonization in New York State (2020).
112. *Id.* at 11.
113. *Id.* at 46.
114. *See* Lee Beck, *Seven Carbon Capture Policy Priorities for the Biden-Harris Administration*, Clean Air Task Force, Dec. 4, 2020, https://www.catf.us/2020/12/seven-carbon-capture-policy-priorities-biden-harris-administration/.
115. Ian Austen, *Canada Supreme Court Rules Federal Carbon Tax Is Constitutional*, N.Y. Times, Mar. 25, 2021, https://www.nytimes.com/2021/03/25/world/canada/canada-supreme-court-carbon-pricing.html.
116. Francesco Arena et al., *Latest Advances in the Catalytic Hydrogenation of Carbon Dioxide to Methanol/Dimethylether*, *in* Transformation and Utilization of Carbon Dioxide 103 (Bhalchandra Bhanage & Masahiko Ardi eds., Springer 2014), *available at* https://link.springer.com/chapter/10.1007%2F978-3-642-44988-8_5.

To do so would require amending the Energy Independence and Security Act of 2007 (EISA),[117] specifically the RFS and the CCUS provisions.[118] Additionally, there are a number of broader-scope measures that the federal government can employ to incentivize demand growth of CNHCs, such as by modifying vehicle emissions standards significantly upward while excepting CNHC-powered vehicles, establishing priority fuel taxing regimes or eliminating CNHC fuel taxes altogether for both retail and wholesale consumption, changing federal procurement standards, and incorporating the amended RFS into nonautomotive fuel requirements (such as maritime and aviation fuels).

The most recent calculated economics for production of CNHCs, published in 2008, assumed air capture costs of \$100-\$200/ton $CO_2$, and determined production costs of CNHCs ranging from \$23.50-\$30 per gigajoule (/GJ).[119] The same author's 2018 update compared DAC costs with prior estimates and determined an updated $CO_2$ capture cost range of \$94-\$232/ton $CO_2$ and \$107-\$249/ton $CO_2$, based on separately modeled variants.[120] Based on this data, which reveal the initial 2008 cost estimate to have been quite prescient, a price comparison of CNHC fuel at ~\$30/GJ and chemically comparable premium unleaded gasoline (with an average cost in the United States of \$2.483/gallon as of November 30, 2020) at a cost of \$18.810/GJ (1,000 megajoules (MJ)/gallon of premium gasoline/132 MJ) x \$2.483/gallon of premium gasoline) reveals that with current federal incentives, automotive transportation fossil fuel costs are ~38% lower than projected CNHC costs (not accounting for a minor variation due to available 45Q offset credits). This demonstrates a clear need for government fiscal intervention to generate widespread adaptation if this technology is to survive.

There are a number of policy pathways that can increase DAC $CO_2$ output demand, and a comprehensive strategy needs to be put in place to stimulate demand. Many pathways can be based on existing federal policy frameworks, whereas others will require a build-from-the-ground-up approach. Many of the proposed policy pathways function independently and, if fully implemented, could put DAC deployment and resultant output on track for long-term needs. Other policies may be interdependent and may need ancillary support in order to achieve the maximum effect. Therefore, it is essential that implementation of any of these policies be comprehensive in nature to account for potentially wide-ranging effects.

### *A. Amending the EISA*

Enacted into law in 2007, the EISA[121] was designed to move the United States toward greater energy independence and security, by focusing on three primary areas: Corporate Average Fuel Economy (CAFE) standards, RFS, and appliance/lighting efficiency standards. Of these areas, the RFS has the greatest application to DAC and potential CNHC production. The capacity of the industry to use this captured $CO_2$ to directly synthesize carbon-neutral, liquid fuels to replace gasoline, diesel, aviation, and maritime fuels is dependent on necessary modifications of the EISA to expand fuel pathways.

In order to expand fuel eligibility, in addition to the aforementioned 45Q modifications discussed above, Congress must expand eligibility by amending the RFS and the CCUS provisions. At present, the RFS addresses only biomass-based diesel and biodiesel. In the absence of DAC-based renewable fuels, there is no policy guidance for industry operators, nor can operators take advantage of statutory grants for production of advanced fuels (as is the case with advanced biofuels).

Therefore, the definition of "renewable fuel" (the EISA currently defines the term to mean "fuel that is produced from renewable biomass and that is used to replace or reduce the quantity of fossil fuel present in a transportation fuel"[122]) needs to be modified to "fuel that is produced from renewable biomass *or produced from point-source or ambient atmospheric carbon capture and chemical synthesis* and that is used to replace or reduce the quantity of fossil fuel present in a transportation fuel." Further, 42 U.S.C. §17022, which establishes grant programs for the production of advanced biofuels, must also be modified in parallel with the proposed text above to expand CNHC production potential.

Outside of the RFS, the EISA also sets forth a requirement for the Secretary of Energy to carry out a program "to demonstrate technologies for the large-scale capture of carbon dioxide from *industrial sources*."[123] In making awards under this program, the Secretary is required to select, as appropriate, "a diversity of capture technologies to address the need to capture carbon dioxide from a range of *industrial sources*."[124] The scope of these requirements must be modified to ". . . industrial sources *and ambient direct air capture*." The scope of the awards under this program[125] must likewise be modified as above to "Awards under this section [§17251(a)(2)] shall be only for the portion of the project that—(A) carries out the large-scale capture (including purification and compression) of carbon dioxide from industrial sources *and from ambient direct air capture*." Additionally, §17251(a)(2)(B) must be modified to "Awards under this section shall be only for the portion of the project that—(B) provides for the transportation and

117. 42 U.S.C. §§17021-17054 (Subchapter II: Energy Security Through Increased Production of Biofuels), §§17251-17272 (Subchapter VI: Carbon Capture and Sequestration).
118. 42 U.S.C. §§17021-17022; 42 U.S.C. §§17251-17272.
119. Zeman & Keith, *supra* note 22, at 3910.
120. Keith et al., *supra* note 16, at 1590.
121. 42 U.S.C. §§17001-17386.
122. Pub. L. No. 110-140, §201(J), 121 Stat. 1521 (2007).
123. 42 U.S.C. §17251(a)(1) (emphasis added).
124. *Id.*
125. *Id.* §17251(a)(2).

injection of carbon dioxide, *or for the synthesis of sequestered carbon dioxide into alternative fuel sources*."

### B. Modifying Emissions and Performance Standards for Moving Sources

Another policy pathway that the federal government could undertake would be to modify existing moving source emissions standards under Title II of the CAA.[126] Presently, fuel standards under Title II, §7545 must meet copious requirements concerning the volatility, oxygen content, sulfur concentrations, viscosity, corrosivity, and other qualities and components of fuels commercially marketed to be combusted for energy, as well as for special engine uses. While synthetic fuels can indeed be made in a carbon-neutral manner, they would likely still require additives for engine performance under various conditions. One potential pathway toward expanding CNHC adaptation would be to establish explicit exceptions/favored treatment for DAC-based CNHC fuel performance standards, or simply to exempt such fuels altogether from standards that are imposed on existing transportation fuels.

Additionally, §7546(b) calls for a loan guarantee program, §7546(c) authorizes relevant appropriations, and §7546(d) establishes renewable fuel production R&D grants, all of which focus on biomass-based ethanol feedstock. To expedite deployment of broader fuel pathways, Congress should also consider expanding the eligible feedstocks under this section.

DAC-based CNHCs can be made into a range of synthetic materials and fuels beyond conventional automobile fuel. This has the advantage that "hard-to-electrify" sectors such as aviation or long-distance heavy transportation (e.g., maritime shipping) can be "indirectly electrified" via production and utilization of synthetic CNHC fuels such as methane or Fischer-Tropsch fuels as well as a range of other products (e.g., polymers), all of which have historically relied on fossil-based feedstocks.[127] Incorporating changes made to the CAA in these other transportation sectors may allow for broader and deeper demand, which could yield greater production efficiencies, lower costs, and technological advances.

In the aviation context, the International Civil Aviation Organization (ICAO) has a program to develop technologies in the area of sustainable aviation fuels, which the ICAO identifies as one element of the ICAO basket of measures to reduce aviation emissions, which also includes technology and standards, operational improvements, and the Carbon Offsetting and Reduction Scheme for International Aviation. In the maritime context, the International Maritime Organization (IMO) has imposed regulations to reduce sulfur oxide emissions from heavy fuel "bunker" oil in ship propulsion. This regulation first came into force in 2005 under the International Convention for the Prevention of Pollution From Ships. In both contexts, the ICAO and the IMO could look to adopt DAC-based CNHC fuels.

### C. Establishing Federal Mandates for DAC-Based Fuels

Likely the most powerful policy pathway that the federal government could undertake to achieve broad demand and adaptation for DAC-based CNHCs would be to establish federal mandates for increased use of DAC-based fuels over a certain timetable, which would likely include specific CNHC fuel taxing regimes (or eliminate CNHC fuel taxes altogether for both retail and wholesale consumption). Through either congressional or executive action, the federal government could choose to establish a stand-alone mandate for carbon-neutral, "drop-in" fuels to increase consumption of DAC-derived fuels. This mandate would ideally extend to federal procurement standards as well, in which the General Services Administration could launch a competitive procurement program for carbon removal from DAC and establish a federal contract with the DAC operators to purchase a certain volume of DAC fuel across the entire government transportation fleet. In this scenario, the U.S. Department of Defense could ramp up competitive procurement of DAC-based fuels "from zero to roughly 23% of 2017 operational fuel consumption by 2030."[128]

As part of such action, the Biden Administration and Congress could also seek to establish a federal "Carbon Removal Administration" that could mandate public procurement, codify a permanent version of the 45Q tax credit, or "authorize a new public agency . . . that would receive dedicated funding to remove a specified amount of $CO_2$ each year . . . with sole responsibility for achieving negative-emissions goals."[129] The Rhodium Group, in proposing this latter option, notes that pursuing this option would entail "separate policies to accelerate energy efficiency, end-use electrification, decarbonization of the electric power sector, and other mitigation and carbon removal actions that would be necessary to meet the ambitious GHG reduction targets" set forth by the 2015 Paris Agreement.[130]

A federal (and perhaps state) mandate could also seek to modify the appropriate I.R.C. concerning fuel taxes, and choose to exempt DAC-based CNHC fuels. Under the CAA, "gasoline" is defined as "any fuel sold in any State for use in motor vehicles and motor vehicle engines, *and* commonly or commercially known or sold as gasoline."[131] Should the government choose to go this route, avoiding classification of CNHC fuels as "gasoline" in lieu of an alternative classification (such as "syngas" or some other appropriate variation) would allow for recycled and syn-

126. 42 U.S.C. §§7521-7590.
127. Beutler et al., *supra* note 6, at 4.

128. Larsen et al., *supra* note 39.
129. *Id.*
130. *Id.*
131. 40 C.F.R. §80.2(c) (2020) (emphasis added); *see also* 42 U.S.C. §7545 (regulation of fuels).

thetic fuel utilization to obtain greater economic parity with the existing single-use, carbon-positive fuel market that dominates today.

Given DAC technology's location-independent nature, Congress could also seek to address the fuel tax issue by classifying fuels produced for interstate sales versus fuels produced and marketed in-state. While obviously some fossil fuels would fall within this category, DAC fuel that has no piping infrastructure as a result of in situ synthetization can be made and consumed anywhere. This alternative may invoke Commerce Clause issues, depending on the strictness of interpretation, and whether the DAC activity is judicially determined to be a part of a larger interstate commercial scheme.[132]

### *D. Standards of LCAs*

The aforementioned section on LCA for DAC tax credits would also apply toward integrating LCA for utilizing $CO_2$ as feedstock, and would need to be integrated further into LCA-based regulations and monitoring standards. The IRS should codify approval of DAC-based LCAs if the LCAs show that the DAC-based product results in a permanent neutralization or permanent net decrease in GHG emissions over a broad time period. The impact of the LCA could be measured using EPA's Tool for the Reduction and Assessment of Chemicals and Other Environmental Impacts, or alternatively could be measured by a method of "system expansion" or by "product-specific environmental impacts using the substitution approach."[133] "As the carbon footprint of feedstock $CO_2$ strongly depends on the method used to solve the multifunctionality problem at the $CO_2$ source in a life cycle assessment . . . this ambiguity can potentially lead to suboptimal decisions for the climate."[134] In the absence of known market effects, assessing the difference between existing operations with and without carbon capture by using the substitution approach to imply direct 100% market substitutions "creates a consistent and comparable approach for determining the carbon footprint of $CO_2$."[135]

Boundaries must also seek to define product life-cycle states that the LCA will include, such as "cradle-to-grave" and "cradle-to-gate." The determination of these boundaries depends on the downstream life of the product or service, which may be difficult to assess in a cyclical/renewable fuel economy.

## III. Conclusion

DAC and related CNHC production have the potential to have a consequential role in mitigating climate change and accelerating the push toward a net-negative economy. In this sense, these technologies can act as a bridge toward a more sustainable global economy. DAC deployment and fuel production must complement a broad array of technological advancements in carbon sequestration, power generation, and fuel production/utilization. "Because of the scales likely needed and the time it takes to develop [such technologies], climate policy urgently needs to develop and implement suitable mechanisms to trigger sufficient mitigation and scaling of NETs alike."[136] DAC should not be seen necessarily as a mitigation technology alone, but rather as a piece in the overall strategy of replacing carbon-positive activity.

One essential component of a shift toward a lower-carbon economy is a determination of an environmental merit order for carbon source substitution. In an LCA of DAC, based on Carbon Engineering's commercial-scale plant (capturing ~1 Mt of $CO_2$ annually), the researchers found that the DAC process emits -0.592 kilogram (kg) $CO_2$ equivalent (eq.) from cradle-to-gate for each kg of feedstock $CO_2$.[137] In another study, the authors reported -0.62 kg $CO_2$ eq. for a similar DAC process with slightly different assumptions.[138]

In a comparison analysis with other $CO_2$ feedstock sources (e.g., an ammonia plant (-0.95 kg $CO_2$ eq. per kg of feedstock $CO_2$) and a fermentation plant (-0.94 kg $CO_2$ eq. per kg of feedstock $CO_2$)), the authors found that "the least beneficial scenario is . . . DAC, since it leads to a substantially larger carbon footprint from a system-wide perspective."[139] Consequently, the authors reported that DAC should be utilized only if the $CO_2$ supply capacities of first the ammonia plant and second the fermentation plant are exceeded, noting that "electing an ammonia plant as $CO_2$ source instead of a direct air capture plant could reduce the carbon footprint by 63%."[140] While an environmental merit order is beneficial in present analysis and perspective, federal policy changes that seek to rapidly incentivize a shift toward carbon-neutral renewable energy products will in time improve the entire spectrum of carbon footprints, and thus can shrink the gap in the difference between the various carbon footprints, reducing the importance of the environmental merit order.[141]

Now more than ever, there is a pressing need for a research governance framework in this area of decarbonization. According to the National Academies of Sciences, Engineering, and Medicine's 2019 "Negative Emissions

132. The most recent notable determination of the Commerce Clause in *National Federation of Independent Business v. Sebelius*, 567 U.S. 519 (2012), focused on the requirement set forth in *United States v. Lopez*, 514 U.S. 549 (1995), that Congress regulate only "commercial activity." A likely determination would be that DAC deployment and resultant CNHC production and downstream marketing constitutes "commercial activity." Whether the associated activity is interstate or intrastate remains to be determined.
133. Müller et al., *supra* note 66, at 2989.
134. *Id*.
135. *Id*. at 2990.
136. Beuttler et al., *supra* note 6, at 6.
137. Müller et al., *supra* note 66, at 2985.
138. Melinda M.J. de Jonge et al., *Life Cycle Carbon Efficiency of Direct Air Capture Systems With Strong Hydroxide Sorbents*, 80 Int'l J. Greenhouse Gas Control 25 (2019), *available at* https://repository.ubn.ru.nl/bitstream/handle/2066/199575/199575pre.pdf.
139. Müller et al., *supra* note 66, at 2985.
140. *Id*.
141. *Id*. at 2989.

Technologies and Reliable Sequestration" report, "[a]ppropriate governance of NETs and sequestration is critical because overly lax oversight would lead to ineffective $CO_2$ removal and loss of public confidence, while overly strict oversight would limit deployment. Governance is especially critical when largescale deployment is imminent."[142] The authors of the report note that one way to maintain public confidence during rapid deployment of NETs is "to invest in a substantial effort to educate the public during the research and development stage."[143]

As part and parcel of the policy efforts the federal government should seek to undertake to rapidly decarbonize, it will be essential to educate consumers about their choices and the carbon consequences of their actions in order to justify federal action. This public educational plan will necessarily require an advanced research plan for each phase of program rollout. These plans should be standardized and published in a transparent and understandable format in order to not only lay out the policy justification for likely impending federal action, but also to be a model for global scientific leadership and program replication. President Biden's appointment of a national climate adviser and a presidential climate envoy marks a tremendous step toward elevating the importance of this task at both the domestic and international levels.

In a post-COVID environment, it is highly unlikely that domestic hydrocarbon use will return to pre-pandemic levels. A recent article in *Bloomberg* quotes U.S. Federal Reserve Chairman Jerome Powell as saying that, post-COVID, "we're not going back to the same economy . . . we're recovering, but to a different economy."[144] The article notes that in the short term, "markets for petrochemicals will continue to grow, and both aviation and shipping will be relatively untouched"; however, the article cautions that "it's only a matter of time before tanker ships start running on hydrogen [as] once a technology reaches scale and price parity, conditions can change dramatically."[145] The article cites the example of the domestic coal industry, which not long ago was expected to dominate for decades, yet peaked in 2008 as a result of cheaper natural gas and renewable energy.

The analogies between DAC and renewable energies abound, and there should be little reason that this nascent, yet rapidly developing sector will be any exception. Rather than waiting for the decline of hydrocarbons, which many international oil companies predict may have already peaked, public and private industry alike should work in tandem to accelerate its replacement with sustainable, carbon-neutral, and carbon-negative technologies for energy generation. Steve Oldham, CEO of Carbon Engineering, notes that one of the largest hurdles facing the CCUS industry is existing carbon policy and legislation that favors emissions control but does not enable carbon removal: "We need to see that removing a $CO_2$ molecule from the atmosphere is the same as stopping a $CO_2$ molecule from entering the atmosphere."[146]

In order to achieve this vision, the federal government must immediately begin providing targeted incentives for carbon-neutral and carbon-negative energy options across all sectors of the economy. Implementing the financing pathways, addressing the legal permitting issues, and establishing the federal carbon programs all addressed herein would be a monumental step in the right direction. The transition will take a tremendous amount of regulatory oversight, but such oversight is essential to attain the necessary paradigm shift to a greatly decarbonized and more sustainable future.

142. National Academies of Sciences, Engineering, and Medicine, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda 383 (2019), https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda.

143. *Id.*

144. Tom Randall & Hayley Warren, *Peak Oil Is Suddenly Upon Us*, Bloomberg, Dec. 1, 2020, https://www.bloomberg.com/graphics/2020-peak-oil-era-is-suddenly-upon-us/.

145. *Id.*

146. E-mail from Steve Oldham, CEO, Carbon Engineering, to Author (Sept. 18, 2020, 11:50 a.m. CST) (on file with author).