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House Committee on Science, Space, and Technology, Subcommittee on Energy

Field Hearing: The Future of Advanced Carbon Capture Research and Development

November 22, 2019

Carbon Management: Intersection of Fundamental Science, New Technologies and Policy

The world is growing at an unprecedented pace and scale. The increased and reliable supply of safe, modern, and sustainable energy forms the basis of this transition. The demand for energy continues to grow, not only in the US but globally, with the global population anticipated to reach more than 10 billion people, making it increasingly important to consider both the need for cheap and reliable energy and the environmental consequences of energy production and consumption.

This presents the dual challenge of our times – more energy that is cheap and reliable with fewer harmful emissions. Carbon management enables us to meet this challenge head-on and develop the opportunities it presents in a forward-looking manner. Two separate but related challenges need to be addressed to enable a sustainable energy future: rising anthropogenic carbon dioxide in the atmosphere and the increasing impact of natural gas related to venting, leaks, and flaring.

Human activities currently produce about 36 billion metric tons of CO_2 per year, with over 800 billion metric tons of CO_2 having been added to the atmosphere since the start of the industrial revolution. The size of the problem is evident. The energy industry is the only industry that operates at a scale and positioned to make a substantial reduction on the annual addition and the cumulative addition of carbon to the atmosphere. Integrating novel schemes to capture carbon from point and distributed sources, developing accretive processes to utilize and successfully sequester the carbon can be advanced only through the active engagement of the energy industry, writ large.

The Center for Carbon Management in Energy (CCME) at the University of Houston (UH) was established in January 2019 with the vision of powering the energy transition to a lowered carbon footprint. CCME and UH are partnering with industry and other thought leaders to lead impactful, multi-disciplined and science, business, law, regulations and policy, as well as advancing education to develop a future-ready workforce ready to benefit the society at large. My colleague Tracy Hester, UH Law School, and I created this center in close engagement with our colleagues at UH, industry, and a broad group of stakeholders.

Significant advances have been made towards a diversified, lower emission energy portfolio. These include fuel switching from coal to natural gas in the power sector, increasing the efficiency of both the production and consumption of energy, enabling investment in renewable energy deployment, electrification of transportation, and developing novel technologies to capture carbon dioxide from the atmosphere while finding safe pathways for storage and utilization.

Obstacles to Expanding Carbon Capture Efforts

Currently, technical challenges prevent a rapid scale-up of CO_2 capture. However, economic and regulatory barriers are more consequential in preventing the growth of the CO_2 capture, utilization, and sequestration markets. As my colleagues Tracy Hester and Elizabeth George from the University of Houston Law Center (UHLC) have written, CO_2 is classified as a waste stream rather than a valuable commodity, which prevents access to common carrier pipelines. What this means for the country, and specifically for Texas, is that there is more demand today for CO_2 than the capture and transportation infrastructure can provide.

Within the broader context of the US, there is:

- Significant potential for CO_2 storage in underground deep geological formations as well as storage through enhanced oil recovery (EOR), including offshore capacity for storage and EOR. This, coupled with proximity to sources that produce CO_2, presents an opportunity to significantly reduce transportation costs and infrastructure requirements;
- Local wealth of intellectual capabilities and industrial know-how related to carbon management especially carbon capture and sequestration through EOR, offering a unique and distinctive advantage;
- Nonetheless, legal and regulatory barriers exist, driven in part by the consideration of CO_2 as a waste product. The role and characteristics of injection wells change over the lifetime of the project, leading to classification issues, risk and liability, and pore space ownership issues.

In fact, CO_2 should be regarded as a valuable commodity with a variety of uses and applications that can close the carbon cycle in a manner that is technologically feasible and commercially viable while being self-sustaining in the long term. Disrupting the status quo means this misalignment needs to be addressed through stable and consistent changes to policies. A well-defined cost of carbon is an effective instrument not just for achieving meaningful carbon reduction and environmental protection but would also drive technological innovation, spur new financial strategies to create new market opportunities, and foster continuous socioeconomic development.

The Cost of Carbon

Setting an economy-wide cost of carbon would offer a number of benefits, including:

- Political consensus, willingness, and certainty in support of carbon management and the opportunities it presents;
- A comprehensive and transparent price across all sectors of the economy and all components of different supply chains, in addition to a technology-agnostic approach towards impactful emissions reduction;
- System flexibility as it relates to compliance, border adjustability to avoid double accounting and ensure that the United Sates remains competitive with existing and emerging international costs of carbon;
- A level playing field that allows for new market opportunities and avenues for success for any and all efforts to reduce the carbon buildup, while de-risking market entry and/or upscaling and providing immunity to technological, financial, and legal institutions pioneering carbon management solutions;
- Tangible social benefits, which can help engage citizens and build broad-based public support for carbon management across communities.

Tax credits available through the reformed Section 45Q of the federal tax code, approved as part of the Bipartisan Budget Act of 2018, marked a significant advancement in this direction. It reinforces the principle that carbon management is not peripheral to the United States and that the energy industry will play a critical role as the carbon management landscape evolves, as well as supporting the belief that research, design, and development will drive carbon reduction efforts.

Earlier this year, the Department of the Treasury and the Internal Revenue Service invited public comments on issues arising from the implementation of Section 45Q. The measurement, monitoring, and verification of secure geological storage of qualified CO_2, the standard for measuring recapture of the benefits of the credit, guidance, and clarification on terms and definitions, understanding the boundaries of lifecycles, and understanding structures that can qualify as partners in a partnership for project developers and participating investors are all issues that remain to be addressed. UH and the CCME responded to the request for comments and these are presented in Appendix A.

Projects Are Already Underway

The reforms to Section 45Q have signaled a remarkable paradigm shift for carbon capture, wherein innovation stands to be rewarded and supported by the government. It is through such innovation, intensive research, and field-scale demonstrations across the United States over the last three decades that carbon capture technologies have advanced to their current status, positioning the nation to be a global leader in carbon management. There are no better examples of this deployment than what has been done in the Houston area – the Petra Nova project at the W.A. Parish power plant in Richmond, Texas, just southwest of Houston, which has developed a post-combustion carbon-capture unit coupled with a coal-fired power plant. The captured CO_2 is transported and used for enhanced oil recovery at the West Ranch oil field. As a second example, the NET Power facility in La Porte, a city along the Houston Ship Channel, which is producing net-zero electricity from natural gas.

Building upon the lessons from these projects, well-designed and comprehensive policies can accelerate the scale of deployment and reduce the capital costs and the operating energy cost associated with CO_2 capture. The industry along with academia and the national laboratories, are working on possible solutions, including the replacement of absorbers with adsorption columns, advancing methods to separate oxygen from air that will be able to reduce capital costs and energy requirements.

Currently at the University of Houston we are:

- Advancing modular and intensified carbon-capture technologies for cost-effective and distributed deployment coupled with excess renewable electricity production for the case of direct air capture (DAC). Opportunities to identify better separation and release technologies along with process intensification and simultaneous capture and conversion of CO_2 are key areas of focus at UH. Ongoing development of membrane and electro-membrane technologies along with ntegration into modular and intensified DAC units is underway ;
- Exploring zero-emissions refining to lower and subsequently eliminate gaseous emissions, from process units, fuel headers, and overall plant operations. These gaseous emissions are the primary target for initial consideration. One of the significant areas of research being pursued at UH is the advancement of hydrogen as a source for industrial heating;

- Discovering new and beneficial uses of carbon. The inherent stability of CO_2 means that many traditional processes for converting CO_2 to chemicals is a highly energy-intensive process and hence, produces additional carbon. In contrast to traditional processing methods that focus exclusively on the direct conversion of CO_2 to value-added chemicals, my colleagues here in the Department of Chemical and Biomolecular Engineering, are using CO_2 both as a source of carbon as well as a source of active oxygen that can reduce the energy footprint of existing large-scale hydrocarbon conversion processes such as ethane dehydrogenation.

- Developing new technologies using both computational and experimental work to create the coupled conversion of methane and CO_2 using a combination of low-temperature plasmas and catalysts.

- Advancing novel transportation mechanisms for captured CO_2 to utilize existing infrastructure and enable an international market that treats CO_2 as a gainful global commodity;

- Development of models, practices and operations towards the safe, reliable and permanent CO2 storage in geological formations including saline aquifers, depleted oil and gas reservoirs and unconventional formations. Maximum storage potential estimation and monitoring of the impact on fluid storage on reservoirs, quantification of short- and long- term risks and detection of migration patterns are being advanced through the CCME especially through our outstanding Departments of Earth and Atmospheric Sciences and Petroleum Engineering.

Between 2005 and 2017, fuel switching and a diversified energy mix in the United States resulted in emissions reductions of nearly 760 million metric tons, while delivering low-cost energy to US consumers. In other words, we achieved a 20% reduction in emissions within this time frame on a per capita basis. The vast majority of this decline can be attributed to the dramatic increase in natural gas production from shale, carbonate, and other tight geological formations.

The astounding growth in natural gas production in less than a decade is due to the sheer size and volume of the resources, rapid and continued improvements in technologies such as horizontal drilling and hydraulic fracturing, and the ability of producers to promptly respond to market signals by upscaling production and drilling intensity. That has positioned the U.S. as the largest oil and gas producer in the world, with positive spillover effects such as a more robust domestic manufacturing industry and greater disposable income from reduced fuel costs.

We recognize that capturing emissions, however, only solves part of the challenge facing carbon management. Transportation and utilization form the remaining pillars. The Permian Basin is home to a majority of enhanced oil recovery (EOR) projects in the nation, given its number of large and mature oil fields amenable to CO_2 injection. The first few decades of CO_2-enabled EOR were supported by underground natural CO_2 source fields, but over time these fields have depleted. In addition, size limitations of CO_2 carrying pipelines mean they are unable to support the demand for CO_2 in the region. Moreover, in the absence of an established carbon cost to incentivize capture, capturing industrial CO_2 remains financially unattractive when compared with naturally occurring CO_2.

Other utilization technologies including co-valorization with stranded methane and conversion of CO_2 to plastics and carbon nanomaterials are being advanced at UH. These are early stage ideas that are probing hard scientific questions, but lie at the center of finding increasing societal value for both CO2 and natural gas without impacting the environment.

Similarly, the deployment of carbon storage in the offshore CO_2, especially the Gulf of Mexico, depends on the availability of sufficient high-purity CO_2 captured from near-to-shore industrial sources. The challenge of sourcing can be easily and effectively resolved by optimized source-to-sink matching. Even though sources and at-scale sinks are present, the predominant challenge in connecting the two has been the high cost of transportation and the risks involved in deploying dedicated pipeline infrastructure for long-distance transport, especially for offshore pipelines. Therefore, novel transportation methods such as utilizing dual-use LNG and CO_2 ships that transport LNG one way and carry captured CO_2 on their return journey, allowing the CO_2 to be used for EOR at an appropriate location in proximity to the LNG source site. This is an effective way to reduce the bottlenecks surrounding sourcing of CO_2 and the high cost of transportation via pipelines. This means lessons from projects in the North Sea and extensive experience from the Permian Basin can be easily transferred to advance CO_2-based EOR in amenable offshore Gulf of Mexico fields and the broader objective of carbon management in the U.S.

The growing energy demand in emerging economies such as India presents an opportunity to analyze how carbon management can be developed in regions that will continue to predominantly rely on fossil fuels to meet their energy needs. A UH project, led by world-renowned petroleum engineer Dr. Ganesh Thakur, in collaboration with Oil India Limited (OIL) in the Indian state of Assam has demonstrated how CO_2 captured from nearby petrochemical plants can boost oil recovery in a nearby depleted oil field. Opportunities such as this present a fertile exploratory field for research and development, the avenues to acquire global lessons and develop integrated solutions for a low-carbon world.

<table>
<tr><th></th><th colspan="3">CO_2 Value Chain</th></tr>
<tr><th></th><th>Capture</th><th>Transportation</th><th>Utilization and Sequestration</th></tr>
<tr><td>Power Generation</td><td rowspan="4">Novel Capture Technologies:
Adsorption; Selective Membranes; Modular & Distributed; Integration with Renewables

Re-engineering Processes:
Integration; Intensification</td><td rowspan="4">Pipeline Technologies:
Materials, Corrosion & Leak Testing

Shipping of CO_2:
Technologies, Economics & Policies

Compressors & Power Systems</td><td rowspan="4">Conversion:
Fuels
Chemicals
Plastics

Enhanced Oil Recovery:
Conventional
ROZ
Unconventional
Offshore
Water Use & Recycle

Geological Sequestration:
Seismic, Acoustic, Modeling & Policy</td></tr>
<tr><td>Hydrocarbon Exploration & Production</td></tr>
<tr><td>Petrochemical Refining</td></tr>
<tr><td>Chemicals and Fertilizers</td></tr>
</table>

Concerns Over Methane Emissions

This increase in energy production and demand was not matched with a proportionate increase in transport infrastructure, however, specifically in the expansion of pipeline capacity. Fearing a market glut and restricted by the ability to transport natural gas to where it is needed, both domestically and for export, the venting, accidental leaking, and flaring of natural gas continues to challenge the sustainability of natural gas production and transportation.

While CO_2 is the most significant greenhouse gas (GHG), methane is 25 times more potent than CO_2 as a GHG on a 100-year time scale. Similar to the context of CO_2 in carbon management, methane emissions associated with natural gas flaring, venting, and leaks go beyond environmental protection and the health impacts associated with air quality. There is a compelling case for reducing methane emissions.

Natural gas is a valuable commodity with an existing market, ever-increasing domestic and local demand, and is of relatively low carbon-intensity when compared with other fossil fuels. Therefore, the more we reduce methane emissions, the larger the volumes of natural gas that will be available for consumption. Nonetheless, there is potential good news. We have technologically proven and relatively low-cost solutions that can deliver methane emissions reduction at scale. Implementing those solutions, however, has been hampered in part by the fact that most energy producers are unaware of their methane footprints, in part due to the lack of effective monitoring. That has translated to producers underestimating or sometimes incorrectly reporting their emissions. This is strongly indicative of a gap that can be bridged through policy interventions in the form of newer methane standards and reining in on emissions reporting.

Potential Solutions

In this direction, experts at the University of Houston are developing:

- New technologies to quantitatively monitor a broad range of highly distributed assets for natural gas leaks and economically implementing such technologies at field-scale by combining a variety of key advances, including the development of high-quality and high-fidelity sensors based on light and acoustic methods, wireless communications, data analytics, robotics, and automation;
- Sensor systems, deployment technologies, data analytics, artificial intelligence, and machine learning-based tools at the Hewlett Packard Enterprise Data Science Institute, along with robotics and automation focused on asset-integrity management;
- Chemistry and Chemical Engineering experts using molecular-scale modeling along with catalyst synthesis to macroscale process modeling and pilot-scale reaction engineering are addressing issues of hydrocarbon and CO_2 conversions through:
    - decomposition of methane,
    - methane conversion to methanol,
    - oxidative dehydrogenation of ethane,
    - partial oxidation of methane and ethane using CO_2, oxidative coupling of methane,
    - tri-reforming of methane, and
    - the use of non-thermal plasmas for the conversion of methane.
- Skid-based methane conversion technologies that can address gas-to-liquid technologies that are modularized and economically produce specialty liquids ranging from methanol to gasoline.

<table>
<tr><th></th><th colspan="2">Methane and Hydrocarbons</th></tr>
<tr><th></th><th>Emissions: Monitoring and Mitigation</th><th>Conversion and Monetization</th></tr>
<tr><td>Power Generation</td><td rowspan="4">Monitoring:
(i) Remote Monitoring using Drones
(ii) Distributed Acoustic Sensing

Mitigation:
(i) Pipeline Modeling
(ii) Renewable Integration for Pneumatic Valves</td><td rowspan="4">Distributed Catalysis and Power Generation

Conversion:
Fuels (methanol)
Chemicals
Polymers & Materials

Monetization:
Gas Injection EOR</td></tr>
<tr><td>Hydrocarbon Exploration & Production</td></tr>
<tr><td>Petrochemical Refining</td></tr>
<tr><td>Chemicals and Fertilizers</td></tr>
</table>

A Call to Act Now to Lead Carbon Management Globally

Plainly, the near-term challenge for carbon management is rapid deployment to benefit from economies of scale and reductions in cross-chain risks. Currently, we have reliable and commercially proven technology to mitigate the challenge; what we need are market-based solutions incentivized by economics, regulations, and policies that remain stable over time to accelerate early-stage development.

The critical piece of this puzzle, however, is understanding that the objective and nature of carbon management is based on long-term viability, operates on geological time scales rather than human time scales, and goes beyond emissions reduction and the sustainable energy transition. The local and global context of carbon management underpins:

1. Broader energy security and energy diversity to develop reliable and affordable energy options;
2. Preserving existing jobs while creating new opportunities for long-term employment without dislocating or disbanding the substantial technological, financial, intellectual, and social capital that has been invested in and also produced by our energy systems;
3. Minimizing disruption to the economy while ensuring energy access and safeguarding the rights of citizens;
4. Accountability and responsibility towards capacity building and inclusive participation of all stakeholders.

Higher education institutions have a central role in advancing carbon management. The examples of ongoing research and projects at the University of Houston that I have described today are focused on delivering measurable results through technological, financial, policy, and legal breakthroughs. At the heart of these capabilities is the exceptional quality of our academic faculty and researchers. We remain committed to serving the city of Houston, Texas, and the United States through our wide-ranging educational and research offerings, partnerships with local and global entities, and contributions to the community.

APPENDIX A

UNIVERSITY of HOUSTON | ENERGY

CC:PA:LPD:PR (Notice 2019-32)
Room 5203
Internal Revenue Service
P.O. Box 7604
Ben Franklin Station
Washington, D.C., 20044

Re: Request for Comments on Section 45Q Credit for Carbon Oxide Sequestration (Notice 2019-32)

The Treasury Department and the IRS requested comments on issues that should be addressed in regulations to implement section 45Q.

The government is to be commended for making this regulatory project a priority for the upcoming year. Congress has expressed a longstanding and expanding desire to enhance the incentives for carbon sequestration through the tax credit afforded in section 45Q. Section 45Q's predecessor was originally enacted in 2008 to provide a tax credit for sequestration of carbon dioxide,[1] and that prior provision was amended shortly thereafter in 2009.[2] After ten years of the allowance of a tax credit for sequestration of carbon dioxide, Congress, in 2018, expanded the scope of section 45Q so that the tax credit afforded under that provision applies to sequestration of carbon oxide and then substantially increased the amount of the tax credit for carbon oxide captured with equipment placed in service after 2017.[3] Congress also provided that certain applicable facilities would be entitled to the expanded benefits of the new section 45Q tax credit in certain events.[4] Thus, Congress has expressed a longstanding and growing desire to provide increasing levels of tax benefits to motivate carbon sequestration.

With the above backdrop in mind, it bears stating that the Treasury Department and the IRS have the responsibility to ensure that its guidance furthers the climate policy goals that Congress desires to promote through its enactment of section 45Q. In addition, it also bears stating that because the financial incentives provided by section 45Q are essential to creating a sufficient financial incentive for private citizens to voluntarily take-on the responsibility for investing in the climate change mitigation activities that Congress desires to promote, the Treasury Department's guidance with respect to Section 45Q is fundamental in terms of ensuring that the market activity that Congress wants to create does in fact get created.

UH Energy is an umbrella initiative for efforts across the University of Houston system to position the University as a strategic partner to the energy industry by producing trained workforce, strategic and technical leadership, and research and development for needed innovations and new

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[1] See enacted by § 115 of the Energy Improvement and Extension Act of 2008, Division B of Pub. L. No. 110-343 , 122 Stat. 3765, 3829 (October 3, 2008).
[2] See § 1131 of the American Recovery and Reinvestment Tax Act of 2009, Division B of Pub. L. 111-5 , 123 Stat 115 (February 17, 2009)
[3] See § 41119 of the Bipartisan Budget Act of 2018, Pub. L. No. 115-123 (February 9, 2018).
[4] See §45Q(f)(6).

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technologies. Strategically located in the energy capital of the world, UH Energy along with the Center for Carbon Management in Energy (CCME) has engaged with the energy industry to address the issue of managing carbon at a scale that is likely to significantly impact the carbon balance in the atmosphere.

This letter responds to the government's request for comments and addresses six areas to which further guidance and clarification are needed. Several of the comments are explicitly related to areas where the government asked for comments, but at least one of our comments was not explicitly requested. We request that the Treasury Department and the IRS consider all of our comments in its regulatory process. Our specific comments are as follows.

1. **Economic Substance Doctrine.**

   Section 45Q serves as important goal of creating market incentives for private citizens to affirmatively take steps to sequester carbon oxide into secure geological formations. Without such a tax credit, sufficient financial incentives likely would not exist for citizens on their own to engage in such an expensive endeavor. Congress has recognized this fact through its design of section 45Q. For taxpayers who sequester carbon oxide as part of a tertiary recovery operation, Congress expressed a desire to provide a substantial (albeit reduced) amount of section 45Q credit.[5] The taxpayer in the tertiary injection context has sequestered carbon oxide, but at the same time that taxpayer has received another compensating benefit, namely enhanced recovery of oil and gas through the tertiary development operations. So, the amount of the tax credit afforded to the taxpayer under section 45Q is meaningful but objectively much less than the tax credit afforded to taxpayers who sequester carbon oxide in a secure geological formation outside of the tertiary development context.

   Said differently, section 45Q provides taxpayers who sequester carbon oxide into a secure geological formation outside of the tertiary recovery context with a much higher tax credit amount.[6] The increased amount of tax credit for carbon sequestration where no tertiary recovery benefits are created makes sense because the sequestration of carbon oxide in the non-tertiary context necessarily means that the taxpayer will receive no anticipated revenue stream from that carbon sequestration activity. Carbon sequestration in the non-tertiary recovery context necessarily means that the taxpayer will incur solely financial costs to capture the carbon and to sequester it as the taxpayer will not receive any offsetting revenue

[5] See §45Q(a)(4); §45Q(b)(1)(A)(i)(II). The IRS provided set forth a table for the amount of the credit applicable to each year for purposes of section 45Q(a)(4) in Notice 2018-93, Sec. 3, 2018-51 I.R.B. 1041. The amount so established by year is also subject to indexation for inflation after 2026. See §45Q(b)(1)(A)(ii)(II).

[6] See §45Q(a)(3); §45Q(b)(1)(A)(i)(I). The IRS provided set forth a table for the amount of the credit applicable to each year for purposes of section 45Q(a)(3) in Notice 2018-93, Sec. 3, 2018-51 I.R.B. 1041. The amount so established by year is also subject to indexation for inflation after 2026. See §45Q(b)(1)(A)(ii)(I).

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for storing the carbon oxide molecules given that no enhanced recovery of a commercially marketable product (namely enhanced oil and gas recovery) arises in that context. Thus, the entirety of the financial incentive for engaging in carbon sequestration in the nontertiary scenario arises solely from the tax benefit of the allowable section 45Q credits, and Congress tacitly recognized this fact because it gave a larger tax credit benefit to motivate taxpayers to engage in carbon sequestration in that context and necessarily needed to do so as that activity does not create or produce a marketable product (namely no enhanced oil or gas is recovered in that context). The design of section 45Q, therefore, make perfect sense in terms of its calibration of the tax credit benefit to motivate taxpayers to engage in activities that promote climate mitigation policies that Congress wants to promote in a broad range of contexts. But even so, section 45Q's unique design features require the Treasury Department and the IRS to carefully consider how section 45Q's goals should be meshed with generally applicable federal tax principles like the economic substance doctrine.

In 2010, Congress codified the judicially created economic substance doctrine through the enactment of section 7701(o).[7] The judicially created economic substance doctrine provides the government with broad authority to disregard the tax benefits derived in transactions that have no economic substance apart from the tax benefits derived from engaging in the transaction.[8] In relevant part, section 7701(o)(1) provides that in the case of any transaction to which the economic substance doctrine is relevant, such transaction shall be treated as having economic substance only if the transaction changes in a meaningful way (apart from Federal income tax effects) the taxpayer's economic position and the taxpayer has a substantial purpose (apart from Federal income tax effects) for entering into such transaction. The above broad-based economic substance doctrine serves a legitimate purpose of preventing tax motivated transactions that frustrate Congress' desires.

But, application of that doctrine in the context of section 45Q would serve to frustrate Congress' desires, not promote them. In this regard, in the context of an allowance of the section 45Q tax credit in the context of nontertiary sequestration as envisioned under section 45Q(a)(3), there is no other derived financial benefit from the carbon sequestration activities apart from the federal income tax credit benefits afforded by section 45Q. The non-tax benefits for engaging in carbon sequestration are benefits derived by the society at large in the form of the positive climate change benefits derived from removing ambient carbon oxide from the atmosphere. This societal benefit is the substantial purpose that

[7] For an more in depth consideration of the codification of the economic substance doctrine and its impact on the decided case law, see Bret Wells, *Economic Substance: How Codification Changes Decided Cases*, 10 FLORIDA TAX REV. 411 (2010)
[8] See e.g., See Coltec Indus., Inc. v. United States, 454 F.3d 1340 (Fed. Cir. 2006).

Congress sought to further through its enactment and later expansion of the section 45Q tax credit, but as to the particular taxpayer engaged in the relevant carbon sequestration activity this societal benefit represents "an externality" as the taxpayer receives no direct financial benefit in the nontertiary storage context apart from the allowance of the tax credit for engaging in the carbon sequestration activities.

Thus, an important initial question for an appropriately functioning tax credit under section 45Q relates to when and to what extent will the economic substance doctrine be called upon to disallow tax benefits attributable to carbon sequestration activities that by their very nature are conducted solely to obtain the tax benefits of section 45Q. Section 7701(o)(5)(C) states that the determination of whether the economic substance doctrine were relevant to any particular transaction is to be made in the same manner as if section 7701(o) had never been enacted. Thus, if the economic substance doctrine was not relevant to a particular activity or investment prior to the enactment of section 7701(o), the IRS has recognized that it is still not relevant after the enactment of section 7701(o).[9]

Nevertheless, at present, the government has stated that the determination of when to apply the economic substance doctrine is to be done on a case-by-case basis, depending on the facts and circumstances of each individual case.[10] Moreover, the IRS has a ruling policy that it will not provide private rulings on the question of whether or to what extent the economic substance doctrine is relevant to a particular transaction.[11] Thus, at present, taxpayers who cannot meet the profit-motivation safe harbor indicated in section 7701(o)(2) are left with a significant level of uncertainty as to the manner and the extent to which the economic substance doctrine might be used to disallow tax credit benefits derived from carbon sequestration activities when the tax benefits of those activities are the principle reason the taxpayer was motivated to engage in carbon sequestration in the first place. In thinking about this issue, the Treasury Department and the IRS need to ensure that the application of generally applicable tax principles like the economic substance doctrine do not frustrate the goals of section 45Q or else taxpayers will not obtain the tax benefits that are necessary to motivate them to engage in the positive climate change mitigation efforts that Congress seeks to motivate them to conduct.

The Treasury Department and the IRS, therefore, need to provide guidance to indicate that the economic substance doctrine is not relevant to activities that are conducted under the auspices of section 45Q and then need to state that the generally applicable economic substance doctrine would not be used as a basis to disallow the availability of tax credits otherwise allowable under section 45Q. Clarity is needed because the economic substance

[9] See Notice 2010-62, 2010-40 IRB 411
[10] See Notice 2014-58, 2014-44 I.R.B. 746.
[11] See Rev. Proc. 2019-3, Sec. 3.02, 2019-1 IRB 130.

doctrine is an otherwise far-reaching doctrine that if applied to the section 45Q context would frustrate the Congressional intent to provide an explicit tax subsidy to motivate private citizens to engage in carbon sequestration activities that would not otherwise be pursued "but for" the allowance of the section 45Q tax credits. The legislative history to section 7701(o) provides significant support for the Treasury Department to provide the clarity along the lines advocated in this comment letter as the following explanation of the relevance of the economic substance doctrine makes plain:

> If the realization of the tax benefits of a transaction is consistent with the Congressional purpose or plan that the tax benefits were designed by Congress to effectuate, it is not intended that such tax benefits be disallowed. . . . Thus, for example, it is not intended that a tax credit (e.g.,
> section 42 (low-income housing credit), section 45 (production tax credit), section 45D (new markets tax credit), section 47 (rehabilitation credit), section 48 (energy credit), etc.) be disallowed in a transaction pursuant to which, in form and substance, a taxpayer makes the type of investment or undertakes the type of activity that the credit was intended to encourage.[12]

Section 45Q is not listed in the above non-exhaustive list of examples of where Congress' desire to promote some other policy goal would be subverted by the application of the economic substance doctrine. But, section 45Q provides an even clearer case for not applying the economic substance doctrine than several of the illustrative areas cited in the legislative history to section 7701(o) because section 45Q(a)(3) provides a tax benefit for an activity where no other financial gain is posited to exist apart from the tax credit benefits, and so this reality makes section 45Q a unique provision to which general tax principles must recognize as exceptional.

Guidance is needed in regulations because recent private rulings issued by the IRS evidence a reluctance by the agency to disclaim the relevance of the economic substance doctrine in situations where Congress' goals would seem to be frustrated by its application. In this regard, the IRS has on multiple occasions reserved on the issue of whether investments that generate tax benefits under the analogous area of section 45 implicated the economic substance doctrine even though section 45 is cited as an illustrative example for where the economic substance doctrine should not be applicable.[13] The IRS's refusal to rule on the

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[12] See Staff of the Joint Committee on Taxation, Technical Explanation of the Revenue Provisions of the "Reconciliation Act of 2010," as Amended, in Combination with the "Patient Protection and Affordable Care Act" (JCX-18-10, 2010), at 152, n.344.

[13] See PLR 20110500 (Feb. 4, 2011) (IRS refused to rule on whether or to what extent the economic substance doctrine was implicated by the taxpayer's investment in refined coal investment project that was eligible for tax credits under section 45(c)(7)); PLR 201105006 (Feb. 4, 2011) (same); PLR 201105002 (Feb. 2, 2011) (same)

applicability or nonapplicability of the economic substance doctrine was left unexplained in those private rulings, and that's a problem. Consequently, in the context of this current regulatory project, the Treasury Department and IRS need to explicitly make clear that Congress' desire to encourage carbon sequestration activities solely or principally for tax reasons is what Congress envisioned and so by necessity the economic substance doctrine is inapplicable to activities conducted under the auspices of section 45Q. Again, Congress' allowance of a higher tax credit in the context of carbon sequestration into a non-tertiary formation provides tangible evidence of Congress' desire to motivate taxpayer behavior even when there is no other financial benefit in the carbon capture and sequestration context. Thus, given this reality, the economic substance doctrine cannot be applied in the carbon sequestration context as doing so would frustrate Congress' goal of using the tax system to provide the principal or sole financial incentive for taxpayers to engage in the carbon sequestration activities that otherwise would not be financially viable apart from the tax benefits.

Thus, forthcoming guidance by the Treasury Department should indicate that taxpayers who make investments in carbon capture equipment and then uses that carbon capture equipment to sequester the captured carbon oxide will be entitled to a tax credit under section 45Q and will be treated as being engaged in the active conduct of a trade or business regardless of whether or not those carbon sequestration activities ever generate a financial profit apart from the tax benefits derived from the tax credit allowed under section 45Q. In order for Congress' goals to promote carbon sequestration to be realized, forthcoming regulations should make plain that the ongoing cost associated with the conduct of these carbon sequestration activities should be deductible under section 162 and then should make plain that the ability to claim a tax credit under section 45Q will not be disallowed by reason of the economic substance or business purpose doctrines as long as those carbon capture and sequestration activities are actively conducted in the manner Congress desired to promote through the enactment of section 45Q. Applying the business purpose doctrine and the economic substance doctrine in the context of carbon sequestration activities would frustrate the fundamental policy goals that section 45Q was designed to promote.

2. Secure geological storage. For both section 45Q(a)(3) and (4), the captured carbon must be sequestered into a secure geological formation. Section 45Q(f)(2) provides that the Treasury Department, in consultation with the Administrator of the Environmental Protection Agency, the Secretary of Energy, and the Secretary of the Interior, shall establish regulations for determining adequate security measures for the geological storage of qualified carbon oxide. In furtherance of that regulatory directive, Sec. 3.01 of Notice 2019-83 specifically asked for comments on two matters:

    - Are there technical criteria different from or in addition to those provided in the EPA's GHGRP that should be used to demonstrate secure geological storage? Are

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there existing guidelines, standards, or regulations that could be used to demonstrate secure geological storage such as those developed by the International Organization for Standardization (ISO)?

- Should EPA's GHGRP rules continue to be the reporting requirements for purposes of § 45Q, and should an approved MRV Plan from the EPA be received before any §45Q credit can be claimed? Are there any viable alternatives to the subpart RR reporting requirements, such as third party, Department of Energy, or State certification?

As to the first bulleted item, we believe that the government should be open to standards developed by the International Organization for Standardization.[14] We believe that the IRS and EPA should not foreclose the opportunity to be certified by a nongovernmental organization such as ISO.

However, the caution we would like to provide to the Treasury Department and the IRS is that the science is quickly evolving in this arena. Significant discoveries and learning are occurring in terms of carbon sequestration and carbon capture. As a result, any regulatory guidance in this area should not be static and should recognize that best practices and standards are going to evolve. Given this reality, forthcoming regulations should allow certification of a formation as "geologically secure" under safe harbor provisions but then should provide a means to satisfy that criteria under a facts and circumstances test through certification by the EPA, an appropriate state government authority, or through a rigorous nongovernment organization such as the ISO certification process. The regulatory grant of authority under section 45Q(f) is broad, and the Treasury Department should exercise its broad authority under section 45Q(f) to ensure that its regulations provide clarity on what will be considered a secure geological formation but then provide a facts and circumstances test that could be utilized for potential future developments.

As to the second bulleted item, we recognize that the Treasury Department has a legitimate concern that adequate proof should exist that the sequestered carbon oxide has been appropriately secured before a tax credit is allowable under section 45Q. The Treasury Department also is right to understand that other agencies or nongovernmental organizations are likely better positioned to address the specific technical issues related to whether the captured carbon molecules have been stored in a secure geological formation. However, even though the Treasury Department and the IRS need administrable regulations on issues outside of its areas of particular expertise, the regulations nevertheless should take a balanced approach. As long as adequate proof of sequestration into a secure

[14] See International Organization for Standardization, Carbon dioxide capture, transportation and geological storage — Carbon dioxide storage using enhanced oil recovery (CO2-EOR), ISO/FDIS 27916 (2018).

geological formation exists, then the Treasury Department should not bar the allowance of a tax credit under section 45Q simply because of a procedural foot fault when the taxpayer has complied with the substantive directive to which section 45Q is aimed.

Thus, we believe that the government's disallowance of section 45Q tax credits in the fact pattern set forth in FSA 20183701f (May 3, 2013) is overly harsh if the facts in that ruling were such that the taxpayer could have demonstrated that the carbon dioxide had been sequestered into a secure geological formation. The fact that EPA had not pre-approved the taxpayer's sequestration plan as of the time of the taxpayer's filing of its tax return represents a "foot fault" that by itself should not bar the allowance of tax credits under section 45Q. To state that such proof must exist as of the time of the taxpayer's filing of the original tax return represents a procedural trap for the unwary that frustrates the legitimate goals of ensuring that a tax credit is provided to those taxpayers who in fact have substantively engaged in the activity that Congress desired to promote, namely the capture and sequestration of carbon oxide so that it does not become ambient. The intent of the statute and the public policy goal is to ensure that sequestered carbon oxide is placed in a secure geological formation. Certainly, confirmation from an agency with appropriate oversight should be obtained. However, conditioning the availability of the tax credit afforded under section 45Q upon the pre-approval by the EPA sets forth an extra compliance hurdle that potentially limits the tax credit benefits to taxpayers who have engaged in the activity that Congress desires to promote.

In our view, forthcoming regulations should provide a safe harbor that indicates that pre-approval from the EPA of the taxpayer's carbon sequestration plan and compliance with that pre-approved plan would provide certainty that the taxpayer's activities are compliant with section 45Q's substantive requirements, but that should not be the sole means of demonstrating compliance. Absent prior EPA approval of the taxpayer's carbon sequestration plan, the taxpayer should have the burden of proof to demonstrate that its captured carbon was sequestered into a secure geological formation under a facts and circumstances analysis. In this regard, the taxpayer should be given an opportunity to have a fact-finding by the EPA, state agency, or relevant nongovernmental agency to determine whether its carbon oxide molecules have been appropriately stored in a secure geological formation. If the taxpayer can satisfy this burden of proof under a facts and circumstances analysis that relies on the expertise of another agency, then the taxpayer should be afforded with an opportunity for such a determination as doing so allows the taxpayer the opportunity to claim the tax benefits that Congress intended to provide.

3. Recapture of Tax Credit. Pursuant to section 45Q(f)(4), taxpayers must recapture the benefit of any credit allowable under section 45Q(a) with respect to any qualified carbon oxide that ceases to be captured, disposed of, or used as a tertiary injectant in a manner consistent with the requirements of section 45Q.

In Sec. 3.02 of Notice 2019-32, the government asks for comments on the applicable standard that should be utilized to determine whether and to what extent a tax credit should be recaptured. In addition, the government asked for comments specifically on rules for the determination of whether a formation is a secure geological storage when carbon oxide is used as a tertiary injectant.

In our view, the recapture period should simply be the normal period for the statute of limitations for a tax return plus any extensions.[15] The existing limitations period that generally applies to tax returns already provides an appropriate balancing of interest between the taxpayer's desire for repose and the government's need for ensuring appropriate enforcement.

In terms of the standards for determining recapture, we note that the EPA is charged with oversight that includes the ongoing monitoring, reporting, and validation over whether carbon oxide has been captured and for determining whether the sequestered carbon oxide has ceased to be securely stored. Thus, the IRS should look to the EPA or, where appropriate, to a state agency charged with oversight over such facilities. The EPA or appropriate state agency with oversight over these formations should provide safe harbor guidance on the anticipated amount of carbon oxide that is likely to be re-released back into the atmosphere in a tertiary development project. Thus, once the EPA has certified that a formation is a secure formation and provided guidance on what amount of carbon oxide molecules is likely to be re-released in the context of tertiary activities, then that determination should be presumptively accepted pending contrary evidence provided either by the taxpayer, the EPA, or state agency that exercises oversight over the sequestration of carbon oxide.

However, notwithstanding the above safe harbor, the taxpayer should be able to provide scientific evidence to either the EPA or appropriate state regulatory agency to demonstrate that the amount of carbon oxide that has actually been re-released is less than what the EPA safe harbor guidelines anticipated for the taxpayer's tertiary activities. Thus, in our view, the regulations should provide a safe harbor to which taxpayers can rely and then provide a mechanism for taxpayers to demonstrate that the actual carbon oxide release was in fact lower than the safe harbor threshold.

4. Definition of Terms: Carbon Capture Equipment and Qualified Facility. In Sec. 3.03 of Notice 2019-32, the government asked whether guidance is needed to further clarify terms and definitions appearing in section 45Q, such as carbon capture equipment, qualified

[15] See §6501(a).

carbon oxide, direct air capture facility, qualified facility, tertiary injectant utilization, or lifecycle greenhouse gas emissions.

We believe that clarification of these terms would be beneficial to both taxpayers and the government. In particular, the government should clarify the definition of "qualified facility" and "carbon capture equipment." A "qualified facility" is the industrial facility that is the source of the qualified carbon oxide and will often be owned by a party that is different from the taxpayer that will own the "carbon capture equipment." The IRS definition should understand that there is likely to be many different types of facilities and that facilities may have been retrofitted over time. The government should then make clear that the relevant party entitled to claim a tax credit under section 45Q is the taxpayer who owns the carbon capture equipment whether or not that party owns the qualified facility that emitted the carbon oxide.

5. Party Entitled to the Credit. The reality for many arrangements is that multiple parties will be involved in the carbon sequestration process. Except in the case of the largest companies, it is likely to be the case that a carbon sequestration activity will include differing parties that perform one or more of the following functions: (a) one party will emit the carbon oxide at a qualified facility, (b) another party will invest in carbon capture equipment at that facility and will separately own and operate that carbon capture equipment to capture carbon oxide molecules (hereafter referred to as the "Carbon Capture Partnership"), (c) a different party may agree to transport the sequestered carbon oxide molecules through its pipeline to a storage facility, and (d) a final party may own a storage facility and will take custody over the transported captured carbon oxide molecules and then inject those molecules into a secure geological formation.

   Throughout each of these steps in the carbon capture and sequestration supply chain, contractual arrangements will likely exist that set forth the performance obligations of each party and the representations and warranties for each party in terms of its duty of care for ensuring that the captured carbon oxide molecules are not re-released back into the atmosphere. Investors into the entity that owns the carbon capture equipment may well be financial investors that provide the capital for the activities performed by the Carbon Capture Partnership but otherwise may be passive partners. Ownership of the carbon oxide molecules may well pass from the Carbon Capture Partnership to the next party in the supply chain indicated above. In other arrangements, the carbon oxide molecules may remain owned by the Carbon Capture Partnership throughout the transportation and/or injection process and the role of intervening parties may simply be to act as agents with respect to the transport and injection of the carbon oxide molecules for and on behalf of the Carbon Capture Partnership. And, with respect to the carbon oxide molecules that are transported to the injection site, the carbon oxide molecules may be commingled with other carbon oxide molecules that were captured elsewhere by a different Carbon Capture

Partnership, and this commingling would necessarily occur if the carbon oxide molecules are placed into a common carrier pipeline for transportation to a common disposal site.

Forthcoming regulatory guidance needs to be nuanced enough to envision these expected and recurring business complexities but at the same time must also be transparent enough to be administrable for taxpayers and the government.

In Sec. 3.06, 3.07, and 3.09 of Notice 2019-32, the government requested comments on the following:

> .06 Under § 45Q(f)(3)(A), the credit is attributable to the person that captures and physically or contractually ensures the disposal, utilization, or use of the qualified carbon oxide as a tertiary injectant. The Treasury Department and the IRS seek comments on the types of contractual arrangements that investors anticipate with parties who capture or dispose or utilize qualified CO. What are common terms of contracts ensuring the disposal, utilization, or use of qualified CO as a tertiary injectant? What should result if such terms are determined to be insufficient?
> .07 What factors should be considered in determining the time and manner of the election under § 45Q(f)(3)(B) to transfer the § 45Q credit to a person that disposes of the qualified carbon oxide, utilizes the qualified carbon oxide, or uses the qualified carbon oxide as a tertiary injectant? If such an election is made, what issues should be considered regarding the transfer of the § 45Q credit?
> .09. Is guidance needed concerning structures in which project developers and participating investors would be respected as partners in a partnership generating a § 45Q credit? Further, is guidance needed on allocating the credit and recapture of the credit among the partners in a partnership?

We view each of the above three requests as presenting a common issue of what substantive requirements must be satisfied for a taxpayer to be entitled to the tax credit allowed under section 45Q, and so forthcoming guidance should designate one party in these complex supply chains that by default is entitled to the benefits of the tax credit afforded by section 45Q. We recognize that the government needs clear rules so that multiple parties do not submit competing claims of entitlement over the same section 45Q tax credit for the sequestered carbon oxide molecules. We also recognize that several parties in this supply chain have contributed significantly towards the ultimate sequestration of the capture carbon oxide molecules.

In our view, we believe that the government should provide clear guidance starting with when an investor into the Carbon Capture Partnership will be respected as a true partner and then extends that guidance to identifying which party in the entire carbon sequestration supply chain is entitled to claim the section 45Q credits. We believe that such guidance should follow the below framework.

First, as to an investor's right to claim an allocable share of tax credits as a partner in a Carbon Capture Partnership that invests and operates carbon capture equipment, the government needs to provide guidance on when it will respect that financial investor's role as a partner in the Carbon Capture Partnership and when the government will claim that the financial investor is not entitled to be treated as a partner in the Carbon Capture Partnership. To begin with, there is a concern about whether a tax partnership can exist when no expected revenue is going to be generated from the Carbon Capture Partnership's activities. For situations where carbon capture equipment is constructed and operated and the eventual disposition of the sequestered carbon is into a nontertiary formation, the Carbon Capture Partnership will make capital investments into carbon capture equipment and then will incur costs to operate that equipment and then will likely have to pay other counterparties for the cost of transporting and disposing of the captured carbon oxide molecules. The Carbon Capture Partnership may have no revenues from these operations in the context envisioned by section 45Q(a)(3). The only financial benefit derived from the Carbon Capture Partnership in the nontertiary context is again solely the tax credits allowable under section 45Q.

The Supreme Court has indicated that the existence of a partnership for tax purposes depends upon a consideration of all of the facts and circumstances and a determination of whether the parties acted in good faith and with a business purpose to join together to conduct the business of the enterprise.[16] Unfortunately, the determination of whether a valid partnership arrangement exists is one where the courts have used differing tests.[17] For the government's part, the IRS has announced a fifteen factor test for determining whether a partnership is one that would be respected for tax purposes.[18] What is more, the Treasury Department has broad authority to disregard partnership transactions that violate the goals and purposes of subchapter K.[19] The government therefore needs to provide guidance on how a partnership that incurs only costs and does not expect to generate positive revenue nevertheless would be deemed to be a valid partnership that is engaged in an ongoing business for the purpose that Congress designed it to conduct. Congress wants to create a market for carbon capture activities and not simply apply a tax regime on an existing market that exists for nontax reasons. In important instances, section 45Q is attempting to create a market where none existed before. This reality has profound

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[16] See Commissioner v. Culberton, 337 U.S. 733 (1949).
[17] See Bradley T. Borden, *The Federal Definition of Tax Partnership*, 43 HOUS. L. REV. 925 (2006).
[18] See Rev. Proc. 2002-22, 2002-1 C.B. 733.
[19] See Treas. Reg. §1.701-2.

implications as to the manner in which general tax principles are to be applied in the unique context of section 45Q.

Second, as an additional issue, the government should also define what level of risk is necessary for an investor to possess in order to be respected as a partner in a Carbon Capture Partnership. In this guidance, the government needs to recognize that the Carbon Capture Partnership will receive contractual protections from the downstream counterparties who take-over responsibility for transporting and disposing of the captured carbon oxide molecules and for its injection into a secure geological formation. Those contractual protections may also provide indemnity protection if the downstream counterparty fails to act in accordance with their contractual obligations. Those contractual arrangements may also include audit and inspection rights along with the right to receive documentation to indicate that the carbon oxide molecules were properly sequestered into a secure geological formation.

The government's successful litigation in *Historic Boardwalk Hall, LLC v. Commissioner*[20] creates concern over what residual partner-level risk must exist for an investor to be considered a partner in a partnership that conducts activities entitled to obtain a tax credit. In *Historic Boardwalk Hall, LLC v. Commissioner*, the government successfully disallowed rehabilitation tax credits otherwise allowable under section 47 that had been allocated to an investor in a partnership because the court found (at the government's urging) that the particular investor (Pitney Bowes) lacked a meaningful stake in either the success or failure of the underlying partnership activities and thus was not a bona fide partner in that endeavor; thus even though the underlying partnership had engaged in the rehabilitation activities that were intended to be incentivized by Congress, the benefits of the section 47 rehabilitation tax credits were disallowed as the investor in that partnership had simply purchased tax credits and was not a bona fide partner with business risk. The IRS has cited its victory in *Historic Boardwalk Hall* as a basis to disallow monetization structures utilized in the context of section 45 production credits, claiming that the monetization strategies that were posited in the rulings had crossed a line so as to cause the investor to not be viewed as a partner with business risk but simply was an investor who had attempted to purchase tax credit benefits.[21] The investor, according to the government's audit position in those rulings, must be in form and substance a partner with an appropriate interest in the partnership's business activities in order to be entitled to claim the tax credits.

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[20] See Historic Boardwalk Hall, LLC v. Comm'r, 694 F.3d 425, 462–63 (3d Cir. 2012).

[21] See TAM 201729020 (July 21, 2017) (concluding that the parties structured a financial transaction in which Taxpayer facilitated the improper sale of §45 tax credits to an investor with the consequence that the Investor was not entitled to claim the tax credits arising from partnership's activity).

The government's victory in *Historic Boardwalk Hall* had a chilling effect on the tax credit market,[22] and so the IRS in Rev. Proc. 2014-12 provided a safe harbor for when it would not contest an outside investor's entitlement to claim tax credits as a partner in a partnership that conducts the credit-eligible activities.[23] Given that the government has already asserted that its litigating position in *Historic Boardwalk Hall* would be applicable to investors that seek tax credits outside the context of the tax credits that were the subject of that particular litigation, the Treasury Department should expand its safe harbor guidance set forth in Rev. Proc. 2014-12 to provide specific safe harbor guidance for section 45Q so that a partner's status as a partner in a Carbon Capture Partnership is respected and the allocation of tax credits to that partner would not be challenged. As part of that expanded guidance, in terms of making this safe harbor applicable to carbon sequestration, the government should provide affirmative guidance on what contractual protections can exist between the Carbon Capture Partnership and a party that is obligated to assume responsibility for transporting the captured carbon oxide and then to dispose of it into a secure geological formation. Specifically, the IRS should affirmatively state that a prohibited guarantee does not exist if the party responsible for disposing of the carbon oxide warrants that it did in fact dispose of the carbon oxide in a secure geological formation and agrees to indemnify the Carbon Capture Partnership if the EPA or another appropriate agency contests that determination. In a vast number of scenarios, it is unlikely to be the case that the Carbon Capture Partnership will own a secure geological formation. Thus, in many situations, the Carbon Capture Partnership will ask for assurances that the party that will inject the carbon oxide molecules does in fact own a secure geological formation. Contractual representations, warranties, and indemnities with respect to the status of the formation should not create a concern under *Historic Boardwalk Hall*, and forthcoming regulations should make this point plain.

Third, in terms of which party should be entitled to claim the benefits of section 45Q, we believe that forthcoming regulations should provide a default rule that the owner of the carbon capture equipment is the appropriate party to claim the tax credit under section 45Q. However, forthcoming regulations should allow the Carbon Capture Partnership to elect to transfer or assign some or all of the section 45Q credit in whole or in party to another party in the carbon capture supply chain if both parties make a joint election that is binding on both parties. The IRS should develop a form that would be attached to the tax returns of both parties that would set forth how the tax credit would be claimed by each of the parties, and the parties should be bound by the allocation set forth in the joint form. The joint filing of duplicate forms with tax returns of both of the relevant taxpayers would provide the IRS with the means to confirm that the transfer of any section 45Q credit to the other party was

[22] See Richard M. Lipton, New Rehabilitation Credit Safe Harbor—Limiting Historic Boardwalk Hall, 120 J. Tax'n 128 (March 2014).
[23] See Rev. Proc. 2014-12, Sec. 4, 2014-1 C.B. 415.

appropriate and each party consistently reports its share of the tax credits in accordance with the joint election. In our view, this assignment of credit should be an annual election. But importantly, absent a joint election to which the Carbon Capture Partnership joins in making, the Carbon Capture Partnership should be designated as the party that would be entitled to the full amount of the section 45Q credit under the default rule.

The above default rule and election procedure, in combination, would ensure that the Carbon Capture Partnership would be entitled to claim the tax credit allowable under section 45Q. The above framework would provide certainty under the default rule that the partners in the Carbon Capture Partnership would not be disgorged of the section 45Q credit absent the consent of the Carbon Capture Partnership. The ability to assign a portion of the section 45Q credits would allow other parties in the supply chain to obtain value for their participation and contribution without requiring that compensation to be in the form of cash. But having said all of this, the above framework also provides a clear and administrable framework for determining the party entitled to the credit and provides a mechanism to ensure that parties take consistent tax positions with respect to their share of the tax credit.

6. Beginning of Construction. To be eligible for the section 45Q benefits, taxpayers must commence construction on qualifying projects before January 1, 2024. In Sec. 3.08 of Notice 2019-32, the government asks whether guidance is needed on what constitutes beginning of construction.

   The Treasury Department and the Service have published extensive guidance on what constitutes the beginning of construction of a qualified facility under section 45(d). In the context of section 45(d), the government provided two tests for determining when construction of a qualified facility has begun.[24] Under the first test, the beginning of construction can be commenced by beginning physical work of a significant nature (Physical Work Test). Alternatively, under the second test, a taxpayer may establish the beginning of construction by meeting the safe harbor provided (Five Percent Safe Harbor). Both methods require that a taxpayer make continuous progress towards completion once construction has begun (Continuous Construction Test). In the section 45(d) context, the government supplemented these tests with a safe harbor (the Continuity Safe Harbor) that addresses what level of continuous activity must be met in order for construction to be viewed as ongoing.[25] In 2014, the government provided further clarifications to the Physical Work Test.[26] And, in 2015, the government extended the period for the Continuity Safe Harbor by an additional year.[27] Also in 2016, the government further modified the

[24] See Notice 2013-29, 2013-1 C.B. 1085.
[25] See Notice 2013-60, 2013-2 C.B. 431.
[26] See Notice 2014-46, 2014-2 C.B. 520.
[27] See Notice 2015-25, 2015-1 I.R.B. 814.

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Continuity Safe Harbor and the Physical Work Test and provided that the Continuity Safe Harbor Test would be presumptively met if a facility is placed in service by the calendar year that is no more than four calendar years after the calendar year during which construction of the facility began.[28] In 2017, the government further modified the guidance it provided as to the Continuity Safe Harbor and modified other guidance as well.[29]

The above brief review of the government's guidance in the section 45(d) context demonstrates that the government has already expended considerable effort to set forth what constitutes the beginning of construction in an analogous tax credit situation. In our view, forthcoming regulations should simply rely on that existing guidance and extend that guidance to the section 45Q context. We commend the government for the diligence and detailed work it has already incurred in order to provide helpful and clear guidance for taxpayers.

However, we do note two areas where section 45Q should have differing guidance. In our view, the Continuity Safe Harbor should envision a longer period of time than just the four-year period specified in Notice 2016-31 when applied to section 45Q projects. The development of carbon sequestration equipment is ongoing and evolving, and prototypes are being developed and tested. Depending on the type and nature of the carbon capture equipment, these installation projects may be more extensive and require a longer construction period than would normally exist for a project contemplated under section 45(d). Thus, we would encourage the government to allow for a longer presumptive period under the Continuous Safe Harbor Test for a project constructed under the auspices of section 45Q than is currently envisioned in the section 45(d) guidance. As a second point, we think that the Continuity Safe Harbor Test should contemplate that a delay in a project due to the lack of an immediately available pipeline connection should be an excludible disruption in the context of a section 45Q project.[30] Carbon capture equipment will need to be connected to a pipeline that is capable of transporting the captured carbon oxide molecules to an injection site. The timing for construction and completion of pipelines might be subject to unexpected delays due to permitting and other matters that are outside the control of the entity that invests in the carbon capture equipment. Section 4.02 of Notice 2016-31 contemplates various excludible disruptions, and that guidance should be expanded to include delays or disruptions in construction caused due to the lack of an immediately available pipeline connection.

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[28] See Notice 2016-31, 2016-1 C.B. 1025.
[29] See Notice 2017-04, 2017-4 I.R.B. 541.
[30] See Notice 2016-31, Sec. 4.02, 2016-1 C.B. 1025.

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We commend the Treasury Department and the IRS for its detailed list of questions in Notice 2019-32. That notice evidences a real desire by the government to grapple with the substantive questions that must be addressed, and the notice on its face demonstrates that the government has given considerable thought to the policy issues that are at stake. We appreciate the opportunity to have provided comments as part of the Treasury Department's and IRS's regulatory guidance process. Should you have any further questions or would like to discuss our comments more thoroughly, please do not hesitate to context the signatories of this letter.

Sincerely,

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July 4th, 2019

Via Electronic Transmission

CC:PA:LPD:PR (IRS Notice: 2019-32)
Room 5203
Internal Revenue Service
P.O. Box 7604
Ben Franklin Station
Washington, DC 20044

Re: Comments on Notice 2019-32, Credit for Carbon Dioxide Drawdown and Carbon Oxide Sequestration

To Whom It May Concern,

On behalf of UH Energy we are pleased to submit comments in support of Notice 2019-32 for the Request on Comments on Credit for Carbon Dioxide Drawdown and Carbon Oxide Sequestration.

UH Energy is an umbrella for efforts across the University of Houston system to position the university as a strategic partner to the energy industry by producing trained workforce, strategic and technical leadership, and research and development for needed innovations and new technologies. We're located in the energy capital of the world and believe that the section 45Q credits, in their current form, will transform the landscape for the carbon management industry in the US. However, for effective and at-scale carbon dioxide drawdown it is essential to develop global solutions. Our recommendations of treating carbon dioxide as a global commodity and adopting a dual-use shipping system for its multinational trade can position US as a world leader across the carbon management, enhanced oil recovery for hydrocarbon resources, and marine transport industries.

We thank you for your time and for considering our recommendations for Notice 2019-32. We will be happy to provide further clarifications or comments if you have any questions.

Sincerely,

Ramanan Krishnamoorti
Chief Energy Officer
UH Energy, University of Houston

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Executive Summary
The current status of considering and treating carbon dioxide (CO_2) as a waste product is hindering large scale deployment of carbon management. In contrast, CO_2 is, in fact, a valuable commodity with multiple uses and applications that can close the carbon cycle in a manner that is technologically feasible, commercially viable while being self-sustaining in the long-term. However, the commercially viable sources and uses of CO_2 are in geographically and internationally disparate areas. Moreover, since CO_2 is an atmospheric component and rapidly equilibrates across the globe, the capture of CO_2 in any part of the world must be considered as a valuable resource to address carbon management. Therefore, we suggest that multinational CO_2 trade should be encouraged and incentivized to match commercially viable sources and uses.

Among the many uses of CO_2 is its ability to act as a tertiary injectant to enhance oil and gas production. However, not all sites of oil and gas production are viable for tertiary recovery. Identifying sites that are mature and past primary and secondary methods of recovery is crucial for optimized source to use matching for CO_2-based enhanced oil recovery (EOR). Having identified a viable geological site for use of CO_2, it is important to establish the miscibility and wettability of the CO_2 to achieve higher recovery ratios and to ensure that CO_2 does not leak back to the surface. For CO_2-based EOR that warrants these targets, CO_2 has to be available where it's needed. The cost of capture is a critical determinant for CO_2 availability, which in turn depends on the concentration of CO_2 at the capture site and the source of the emissions at the said site. Point source capture sources such as fertilizer plants offer the lowest cost with the highest concentration of CO_2 in the captured stream; while distributed air capture has the lowest concentration and highest costs of capture.

The last and critical link between sources and uses is the transportation of CO_2. CO_2 can be moved between sources and sinks over the lifetime of projects only if efficient, effective, and low cost transportation options exist. To debottleneck the challenges of high costs and risks for the transportation of captured CO_2 multinational trade of CO_2 needs to be addressed. Section 45Q provides the necessary pathways to accelerate the same.

We have examined the commercial viability of dual-use shipping system utilizes vessels which transport exported LNG from the US and carry captured CO_2 on their return journey from the destination of delivery. This can expedite long-distance transport and multinational trade of CO_2 without the costs and risks of conventional pipeline-based transport. This CO_2 can be utilized as a tertiary injectant in amenable fields in the offshore US where CO_2 for EOR is required but scarce, and pipelines are financially intensive or their deployment is fraught with strategic risks. The advantages of a dual-use shipping system are manifold, and discussed in detail in the response.

Background

Reforms to tax credits for carbon dioxide sequestration were passed by Congress in early 2018. Through broad bipartisan support as part of a larger bill- the FUTURE Act (Furthering carbon capture, Utilization, Technology, Underground storage, and Reduced Emissions Act), the reforms are more commonly known as the 45Q tax credit. They are aimed at driving investment in large-scale commercial deployment of carbon management methods. The reformed section 45Q credits are characterized by the following-

- Increases the credit amounts for qualified facilities
- Expands the end-uses for which captured CO_2 may be used
- Modifies the requirements for the amount of CO_2 that must be captured
- Allows certain new industrial facilities, including direct air capture facilities to qualify for the credit if construction begins before 2024
- Allows qualified facilities to claim the credit for 15 years, beginning on the date the equipment was originally placed in service

CO_2 as a global commodity - Why moving CO_2 from one country to another should qualify for Section 45Q?

Curbing emissions as well as removing carbon from the atmosphere is critical for the mitigation of anthropogenic emissions. Although, without large-scale deployment of carbon management techniques, which allow carbon to be a profitable commodity as against its current status as a waste product, the mitigation of emissions at scale with climate targets is unlikely.

Countries vary in their geological storage capacity or the ability to utilize CO_2 as a tertiary injectant due to limited viable fields. Many nations have sequestration potentials well over their rates of emission; while other high emitting nations which are projected to emit at current or higher levels lack comparable capacity for the sequestration of these emissions, even if they were to capture their emissions. Resultantly, it would either be technologically infeasible to sequester the captured carbon from these countries or be commercially unviable to continue capturing CO_2 in the long run. Allowing carbon to be traded as a physical commodity between nations resolves this challenge. Moreover, carbon dioxide takes about two years to level out and disperse globally in the atmosphere. Moving carbon through trade from one country to another, which would otherwise equilibrate through the global atmosphere regardless, and sequestrating it can mitigate the imbalance between sources of emissions and viable carbon sinks amongst different nations. Even though sources and at-scale sinks are present, the predominant challenge in connecting the two has been the high cost of transportation and the risks involved in deploying dedicated pipeline infrastructure for long-distance transport, especially for offshore pipelines.

Why is dual-use shipping important?

As discussed above, transporting CO_2 via pipelines has proven expensive or prohibitive for projects. The current pricing structure suggests that transport costs constitute 12-16% of the total cost of carbon management projects that are based on carbon capture, utilization, and storage techniques for point-source capture. However, these estimates are highly project specific; depending on the distance and mode of delivery the costs can escalate to about 40% of total costs for some cases. Adopting a dual-use shipping mechanism can eliminate a bulk of this cost to allow economically feasible transportation of CO_2 over long distances. Dual-use shipping utilizes vessels that transport LNG one way and carry captured CO_2 on their return journey, allowing the CO_2 to be used for EOR at an appropriate location in proximity to the LNG source site. Specifically for the purpose of section 45Q, transporting CO_2 via dual-purpose ships that carry LNG from the US and CO_2 back to the US on its return journey will allow the CO_2 to be then utilized as a tertiary injectant for enhanced oil recovery (EOR). This would-

- Eliminate the cost of operating an empty ship on its return journey
- Optimize sources to use coordination and transporting CO_2 over long distances at a fraction of the current costs
- Accelerate the development of multiple parallel projects based on demand and supply and eliminate the need for dedicated infrastructure that results in sunk costs at the end of the project's lifetime
- Provide a market for CO_2 mitigation
- Provide secure and permanent locations for utilizing CO_2
- Transform the pricing structure for carbon management by eliminating any potential regulatory support for transportation of CO_2 and focus regulatory support for carbon capture and carbon utilization and storage.

With fuel costs making up about 60% of operational expenses, an empty vessel on the return journey is a lost commercial opportunity. Fuel consumption for a cargo-free vessel is only about 25%-30% less than that for a laden LNG vessel. For a 250,000 m3 LNG vessel that consumes about 220 tons of bunker fuel per day. If the vessel were to be used for dual-use shipping and forgo the 30% reduction in fuel consumption by loading it with CO_2 – at $440 per ton for bunker fuel and assuming a one-way journey of 14 days–more than 300,000 tons of CO_2 could be transported at $1.5 per ton. From a logistical perspective, CO_2 is often produced at points close to LNG offloading, for example at refineries or chemical plants in close proximity to the shore. On the other hand, CO_2 demand for EOR is close to sources of natural gas as well. At this price of transportation, logistical convenience, matching supply with demand, and with the added value of fossil fuel recovered through EOR, dual-use shipping can accelerate large-scale deployment of carbon management. Global energy related CO_2 emissions for 2018 were ~33 Gt. If even a tenth of this were to be utilized for EOR through multiple parallel projects, the revenue from additional oil produced (at an average of 2.5 barrels per ton of CO_2 and priced at $59 per barrel) is a robust

$4.4 trillion dollars in revenue for the industry, along with carbon-negative fossil fuel production. This can advance multi-national partnerships between

- Those who produce fossil fuels in the US and export LNG outside of the US
- Those who capture carbon outside of the US and import LNG from the US.

What does utilization mean for carbon management?
Geological storage without utilization, which does not result in a commercial end-use of carbon dioxide, would remain a cost center despite the credits applied through section 45Q. In contrast, carbon management can be made a commercially viable and self-sustaining opportunity only through utilization. While the carbon management industry is not mature enough to settle on a single end-use approach for now, utilization provides pathways for carbon management which are environmentally safe and benign, allows trade beyond small niche markets, and guarantee long-term stability. Hence, the carbon cycle can be closed in a commercially and environmentally profitable manner. Trading as a commodity would also make assigning ownership, liability, and benefits more efficient since firmly established and well-documented international trade rules will apply to the movement of CO_2 via dual-use vessels.

What would this mean for carbon management?
A dual-use shipping system enables a least cost pathway for advancing carbon management by creating modifications within existing frameworks and infrastructure. The system also relies on mature industry experience from the oil and gas industry for the utilization of CO_2 as a tertiary injectant for EOR, and marine industry for transport while notably advancing the relatively immature carbon capture industry. In the process, carbon is traded as a profitable commodity, which would not need incentives in the long-run.

Recommendations- What needs to be addressed for Section 45Q?
We need to consider multi-national trade and storage as part of the guidelines for Section 45Q. For this:

- The definition of qualifying carbon dioxide and qualifying facility need to include specifications on imported CO_2 as well as on applicable dollar amount and payout mechanism for the said CO_2.
- Since the qualifying facility in a dual-use shipping system will be located outside of the US, joint ventures and MoU which have a US based partner should qualify for the credits as applicable in Section 45Q. The definition of qualifying facility should also be expanded to include provisions for the applicable dollar amount to be shared amongst multiple parties and/or investors. Further guidance is needed on the structure of such partnerships and potential contractual agreements.

- Standards established by the World Trade Organization (WTO) can be employed to supplement determining the amount of qualified carbon dioxide when transported using dual-use vessels. Inventory analysis and management are established marine industry practices which can supplement lifecycle greenhouse emissions analysis under section 45Q. This would require the expansion of reporting guidelines to include WTO standards.
- Greenhouse Gas Reporting does not include guidelines on utilization through means other than EOR. Guidance is required on how qualified carbon, qualified facility, and subsequent credits be determined for utilization processes as mentioned in section 45Q(f)(5)(A).

Appendix A

Terms and Definitions

For the purpose of this document,

1)The term "qualified carbon oxide" means—

(A) Any carbon dioxide or other carbon oxide which

(i) Is captured from an industrial source by carbon capture equipment which is originally placed in service on or after the date of the enactment of the FUTURE Act of 2018,

(iii) Is measured at the source of and verified at the point of disposal, injection, or utilization

Or

(B) in the case of a direct air capture facility, any carbon dioxide which

(i) Is captured directly from the ambient air

(ii) Is measured at the source of capture and verified at the point of disposal, injection, or utilization.

2) The term "taxpayer" means any person subject to a tax under the applicable law.

3) The term "tertiary injectant" means any injectant, other than a hydrocarbon injectant which can be recovered which is used as a part of a tertiary recovery method. The term "hydrocarbon injectant" includes natural gas, crude oil, and any other injectant which is comprised of more than an insignificant amount of natural gas or crude oil.

5) The term "calendar year" means a period of 12 months ending on December 31.

6) The term "direct air capture facility" means any facility which uses carbon capture equipment to capture carbon dioxide directly from the ambient air.

7) The term "applicable dollar amount" shall be an amount equal to—

(i) for any taxable year beginning in a calendar year after 2016 and before 2027—

a) the dollar amount established by linear interpolation between \$22.66 and \$50 for each calendar year during such period

b) the dollar amount established by linear interpolation between \$12.83 and \$35 for each calendar year during such period, and

(ii) for any taxable year beginning in a calendar year after 2026—

(a), an amount equal to the product of \$50 and the inflation adjustment factor for such calendar year determined under section 43(b)(3)(B) for such calendar year, determined by substituting "2025" for "1990", and (II) an amount equal to the product of \$35 and the inflation adjustment factor for such calendar year determined under section 43(b)(3)(B) for such calendar year, determined by substituting "2025" for "1990".

8) The term Class VI wells means wells that are used to inject CO_2 into deep rock formations. This long-term underground storage is called geologic sequestration. Geologic sequestration refers to technologies to reduce CO_2 emissions to the atmosphere and mitigate climate change.

9) Greenhouse Gas Reporting Rule
The US EPA mandates reporting of greenhouse gases (GHG) from sources that emit 25,000 metric tons or more of carbon dioxide equivalent (CO_2e) per year in the United States. However, the rule, 40 CFR 98, published on October 30, 2009, does not include smaller sources or sectors such as agricultural or land use change. The program is more commonly referred to as the Greenhouse Gas Reporting Program (GHGRP) and is aimed at providing a comprehensive understanding of the sources of GHGs and to guide development of policies and programs to reduce emissions. 40 CFR 98 applies to direct greenhouse gas emitters, fossil fuel suppliers, industrial gas suppliers, and facilities that inject CO_2 underground for sequestration or other reasons.

According to the EPA, suppliers of CO_2 (subpart PP) covers facilities that capture CO_2 from industrial sources and processes or extract it from natural CO_2-bearing formations for supply into the economy. Underground injection of CO_2 (subpart UU) covers facilities that inject CO_2 underground for enhanced oil and gas recovery (EOR), acid gas injection/disposal, carbon storage research and development (R&D), or for any other purpose other than geologic sequestration. Geologic sequestration of CO_2 (subpart RR) provides a mechanism for facilities to monitor and report to EPA amounts of CO_2 sequestered. Facilities submit a plan for monitoring, reporting and verifying CO_2 sequestered underground. Once the plan is approved, facilities report basic information on CO_2 received for injection, data related to the amounts of CO_2 sequestered, and annual monitoring activities.

For subpart PP, suppliers of CO_2 consist of the following:

- Facilities with production process units that capture and supply CO_2 for commercial applications that capture and maintain custody of a CO_2 stream in order to sequester or otherwise inject it underground.
- Facilities with CO_2 production wells
- Importers of bulk CO_2, if total combined imports of CO_2 and other GHGs exceed 25,000 tons of CO_2 equivalent (CO_2e) per year.
- Exporters of bulk CO_2, if total combined exports of CO_2 and other GHGs exceed 25,000 tons CO_2e per year.

This source category does not include entities that store CO_2 through geologic sequestration or above ground storage; use CO_2 in enhanced oil and gas recovery; transport or distribute CO_2; purify, compress, or process CO_2; or import or export CO_2 in equipment.

The subpart RR source category comprises a well or group of wells that inject a CO_2 stream for long-term containment in subsurface geologic formations. All wells permitted as Class VI by the

Underground Injection Control (UIC) program meet the definition of this source category. Under subpart RR, facilities that conduct geologic sequestration by injecting CO_2 for long-term containment in subsurface geologic formations are required to:

- Report basic information on CO_2 received for injection.
- Develop and implement an EPA-approved site-specific MRV plan
- Report the amount of CO_2 geologically sequestered using a mass balance approach and annual monitoring activities.

Geologic sequestration research and development (R&D) projects will be granted an exemption from subpart RR. A project is eligible for the subpart RR R&D exemption if it will investigate practices, monitoring techniques, injection verification or is engaged in other applied research that will enable safe and effective long-term containment of a CO_2. To receive a subpart RR R&D exemption, the reporter must submit to EPA information on the planned duration of CO_2 stream in subsurface geologic formations, including research conducted as a precursor to long-term storage. Facilities that receive an R&D exemption from subpart RR are not exempted from any other source category of the GHG Reporting Program including subpart UU.

Under subpart UU, all other facilities that inject CO_2 underground such as for enhanced oil and gas recovery or any other purpose, are required to:

- Report basic information on CO_2 received for injection
- Facilities that report under subpart RR for a well or group of wells are not required to report under subpart UU for that well or group of wells.
- Facilities that conduct enhanced oil and gas recovery are not required to report geologic sequestration under subpart RR unless
  - the owner or operator chooses to opt-in to subpart RR
    or,
  - the facility holds a UIC Class VI permit for the well or group of wells used to enhance oil and gas recovery
- Geologic sequestration R&D projects will be granted an exemption from subpart RR. Projects receiving a subpart RR R&D exemption are required to report basic information on CO_2 received under subpart UU.

11) Monitoring, Reporting, and Verification Plan (MRV Plan)
Facilities that are subject to Subpart RR and are issued a final Underground Injection Control (UIC) permit (any class) on or after January 1, 2011 are required to submit a Certificate of Representation 60 days prior to submission of a proposed Monitoring, Reporting, and Verification (MRV) plan or Research and Development (R&D) project exemption request.

12) The term “carbon management” means human efforts to reduce anthropogenic carbon dioxide from the atmosphere, and permanently and safely sequester it.

How does the credit apply?

The value of the credit that can be claimed is based on:

- Method of use and disposal of qualified carbon
- Date of carbon capture equipment is put on service

For facilities placed in service prior to February 9, 2018, credits can be claimed by those who capture qualified carbon oxide from a qualified facility in a taxable year beginning after October 3, 2008, and meet all of the other requirements of section 45Q. For qualified facilities placed in service after February 8, 2018, the credit is available to those who own the carbon capture equipment and meet all of the other requirements of section 45Q.

For carbon capture equipment originally placed in service at a qualified facility before February 9, 2018,

(i) the credit amount is either

(A) $20 per metric ton of qualified CO_2 and is captured and disposed of in secure geological storage and is not

(1) used as a tertiary injectant in a qualified EOR project and disposed of in secure geological storage

(2) utilized through

(i) the fixation of such qualified carbon oxide through photosynthesis or chemosynthesis, such as through the growing of algae or bacteria,

(ii) the chemical conversion of such qualified carbon oxide to a material or chemical compound in which such qualified carbon oxide is securely stored,

(iii) the use of such qualified carbon oxide for any other purpose for which a commercial market exists (with the exception of use as a tertiary injectant in a qualified enhanced oil or natural gas recovery project)

Or

(B) $10 per metric ton of qualified CO_2 and is captured by the taxpayer, used by the taxpayer as a tertiary injectant in a qualified EOR project, and is used as

(1) for a qualified EOR project and disposed of in secure geological storage

(2) utilized in a manner as described above in (A) (iii) (Section 45Q (f) (5))

ii) For any taxable year beginning in a calendar year after 2009, section 45Q provides for an equal amount of the product of the credit amount and the inflation adjustment factor for the said calendar year.

For any capture equipment put in service on or after February 9, 2018, the credit applies as follows:

Type of CO_2 storage/ use	Minimum size of eligible carbon capture plant by type ($ktCO_2$/yr)			Relevant level of tax credits in a given operational year (USD/tCO_2)								
	Power Plant	Other Industrial facility	Direct Air Capture	2018	2019	2020	2021	2022	2023	2024	2025	2026
Dedicated Geological Storage	500	100	100	28	31	34	36	39	42	45	45	50
Storage via EOR	500	100	100	17	19	22	24	26	28	31	33	35
Other utilization processes	25	25	25	17	19	22	24	26	28	31	33	35

Source: IEA, 2018

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CCME
Center for Carbon Management in Energy

CCME Report from the 45Q Symposium

Authored by the Center for Carbon Management in Energy

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Report Contributors

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McConnell is currently a board member of the Energy & Environmental Research Center (EERC) Foundation in North Dakota, is a member of the National Coal Council, and has held a number of board positions for the Gasification & Syngas Technologies Council and the Clean Carbon Technology Foundation of Texas. He earned a bachelor's degree in chemical engineering from Carnegie-Mellon University (1977) and an MBA in finance from Cleveland State University (1984).

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EXECUTIVE SUMMARY

Carbon capture, utilization and storage, or CCUS, has been identified by the International Energy Agency and the U.S. Energy Information Administration as a critical technology for reducing global CO_2 emissions. The National Petroleum Council has been recently charged by Energy Secretary Rick Perry with studying and making recommendations for the broad commercial deployment of CCUS. And the marketplace is finally at a point where CCUS is no longer simply a topic for institutional research and analysis, but instead a demonstrated commercial opportunity.

The market is in transition. But it is critical that accomplishing meaningful reductions of CO_2 emissions be done in a manner that is accretive to investors. CCUS is not a waste disposal model. It is instead a technology and a solid business investment that reduces CO_2 emissions. Section 45Q of the federal tax code is a key way to create this market movement and to support the objective of a sustainable business investment, although it is not a panacea and will require further modification if it is to help the technologies and business practices reach their full potential.

First enacted in 2008 and subsequently modified, 45Q now addresses all manmade, or anthropogenic, captured carbon emissions and requires new projects to begin construction prior to Jan. 1, 2024, in order to qualify for the credits. In addition to CCUS, the credits have been extended for direct air capture technologies, and the credits for geological storage and enhanced oil recovery have been increased.

45Q presents significant business model potential for the engineered capture of carbon from various sources and for its delivery to a potential endpoint– to enhance oil recovery (EOR) in mature and developing fields while permanently storing the CO_2 in the process or for direct long-term storage, positioning the industry to significantly reduce its carbon footprint.

At the Center for Carbon Management in Energy at the University of Houston, we have identified key drivers and potential obstacles to realizing all that 45Q can enable, including:

a. **The Size of the Prize.** The opportunities for 45Q applications for CCUS in EOR or storage in geological formations have potential both in the U.S. and globally, onshore and offshore. The potential targets are large, and the opportunity is likely to grow as the geologic information and exploration continue to expand into unconventional formations, as well as in previously unexplored regions of the world.

b. **The Permian.** With production of 3.2 million barrels of oil per day in 2018, expected to grow to 7 million barrels per day by 2022, the Permian Basin offers enormous potential for additional recoverable oil in both conventional and unconventional plays. The residual oil zone (ROZ) is a geologic opportunity for oil recovery as impactful as a doubling of recoverable oil potential. There is also substantial geologic capacity to store CO_2 in these formations, and 45Q will make storage a new value proposition. The investment community is already acting upon 45Q opportunities in the region.

c. **Tax Equity Partnerships.** The experience of Core Energy, a midsize exploration company from upstate Michigan, illustrates the realities of implementing CCUS technology, realizing a plan to successfully report measurement and verification to meet IRS standards for 45Q, and the business challenges that remain. While the technology performs effectively and the resulting recovered oil is being produced, the tax structure requirements are not aligned to realize the business benefits without having a tax equity partnership structure in place.

d. **Non-governmental Organizations.** Broad implementation of CCUS requires an alignment of the business and environmental communities. CCUS requires attention to all regulatory requirements, including that CO_2 storage be safe, permanent and verifiable. Regulatory responsibility, coordination and enforcement all will be required, and the business/community partnership is more than simply regulatory compliance but an invitation to operate in the communities and regions affected.

e. **Regional Partnerships.** A decade of research involving regional CO_2 partnerships has progressed the technology and know-how exponentially. Risks associated with geologic storage have been driven to a level suitable for commercial investment. While there is no recipe for determining the exact level of business and commercial risk, the technology is ready for additional commercial opportunity in the market. Partnerships detailed in this paper demonstrate the broad-based opportunities across the US.

f. **Life Cycle Analysis.** Work by the Energy & Environmental Research Center (EERC) at the University of North Dakota has explored the impact of 45Q credits on CO_2 emissions, along with the impact of using the captured CO_2 to produce additional hydrocarbons via enhanced oil recovery projects. Hydrocarbons produced using the captured carbon have a lower net carbon impact than that of non-CCUS produced oil.

g. **It's Happening Today.** The Petra Nova project located near Houston offers insight into a commercially viable CCUS operation.

At the end of this paper is a step-by-step analysis of the most recent 45Q language made ready for public comment during summer 2019. A large segment of a recent workshop hosted by the Center for Carbon Management in Energy was dedicated to this point-by-point analysis. In addition, the analysis speaks to steps and revisions we believe are necessary for the investment community to realize broad commercial deployment. We anticipate this segment will offer a useful review for both the business and legal communities.

Simply put – 45Q has catalyzed the CCUS marketplace at a level not previously seen in the US or elsewhere. But challenges lie ahead if we are to realize broad commercial deployment and the associated investments and environmental impacts. This paper offers suggestions for improvement, necessary clarifications and steps to lower investment risk.

Broad deployment in the US improves the likelihood of its expansion globally. That is real sustainability.

Acknowledgements

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BACKGROUND

Congress has expressed a longstanding and expanding desire to enhance the incentives for carbon sequestration through the tax credit afforded in section 45Q.

Section 45Q's predecessor was enacted in 2008 to provide a tax credit for sequestration of carbon dioxide,[1] and that prior provision was amended in 2009.[2] Congress in 2018 (through the Furthering Carbon Capture, Utilization, Technology, Underground Storage, and Reduced Emissions Act (FUTURE) Act) expanded the scope of section 45Q so the tax credit applies to sequestration of carbon oxides and substantially increased the credit for carbon oxides captured with equipment placed in service after 2017.[3] Congress also provided that certain applicable facilities would be entitled to the expanded benefits of the new section 45Q tax credit in certain events.[4]

45Q clearly has much potential, but it also leaves many topics unclear, leading to risk, concerns and the probability that the maximum impact of CCUS will not be realized.

The Center for Carbon Management in Energy (CCME) engaged with a broad group of stakeholders during a daylong workshop on the Monetization of Carbon, focusing on the technology, legal and policy impacts of Section 45Q.

Based on the belief that successful implementation of CCUS and other carbon management technologies must add value for both the environment and the commercial marketplace, the workshop brought together globally recognized speakers from the energy industry, academia, government and nongovernmental organizations to discuss the challenges and successes. This paper is based on presentations by those speakers and serves as the next step in the center's work to educate participants in the marketplace as well as the workforce of the future, and to be at the center of the solutions required for CCUS to be broadly deployed, commercially sustainable and environmentally impactful.

The workshop discussions were constructed to assess the opportunities for using 45Q across a number of key areas. We also posed some of the unknown challenges.

Key to this discussion is the understanding that CCUS is not a waste disposal model – it is a technology and business proposition that reduces CO_2 emissions and should be supportive of accretive business investment. 45Q is currently the most effective way to create market movement in this area.

THE POTENTIAL SCOPE OF THE RESOURCE

An internationally known geologic resources assessment firm, Advanced Resources International (ARI) has conducted exhaustive studies of target areas for geologic applications of EOR, as well as potential targets for storing CO_2 in formations that can offer a safe and permanent repository. ARI president Velo Kuuskraa offered key findings:

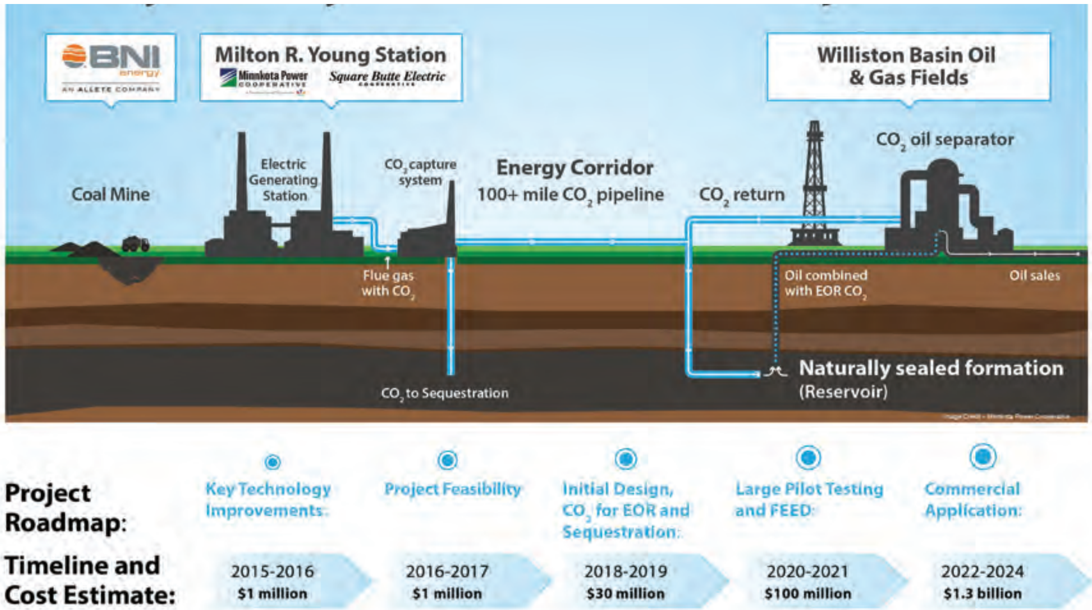
- EOR is not a "niche" opportunity. There is enough geologic capacity in the US and globally to store CO_2 emitted over decades.
- Offshore geologies have recently been explored, revealing great potential for storage targeted to offshore and ultimately deep water formations
- There is strong potential for EOR globally.

Project Tundra (see Figure 1) has recently received project development funding from the US Department of Energy and the state of North Dakota and illustrates the opportunities to deploy CCUS on existing fossil fuel based electricity production facilities – both coal and natural gas. The project will employ both CO_2 long-term storage technology as well as enhanced oil recovery (EOR) and can be structured as an ideal candidate for 45Q treatment for long-term economic benefit.

Much of the developmental project and site scoping has been an ongoing part of the PCOR regional sequestration partnership and the leadership of the Energy and Environmental Research Center (EERC) in North Dakota. This platform of knowledge has provided an opportune project scope to deploy CCUS and validate the value creation from CCUS. The state of North Dakota has made a strong statement to the marketplace that all forms of energy and advanced technologies go hand in hand.

It is interesting to note the common misconception that CCUS is "too expensive."

Figure 1: Utility Industry Carbon Solutions - Project Tundra



Projects such as Tundra establish the real costs, suggesting a cost effective option in a sustainable carbon constrained energy future. The power produced is carbon-free and baseload for 24/7 operations.

It should be noted that the term CCUS in this paper is meant to be inclusive of the term CCS (carbon capture and storage). Our view is that all forms of CCUS – including CCS – offer opportunities and technologies designed to capture CO2 before emission to the atmosphere and that the safe and permanent storage of CO2 is a necessary component. While CCS technically does not speak to "utilization" in the classic form, we consider pure storage and realizing a value for the stored CO_2 is in fact utilization. Although there is a distinction made in the 45Q tax credit structure ($35/ton for "utilized CO_2 in EOR and $50/ton for storage only), the fundamentals remain the same.

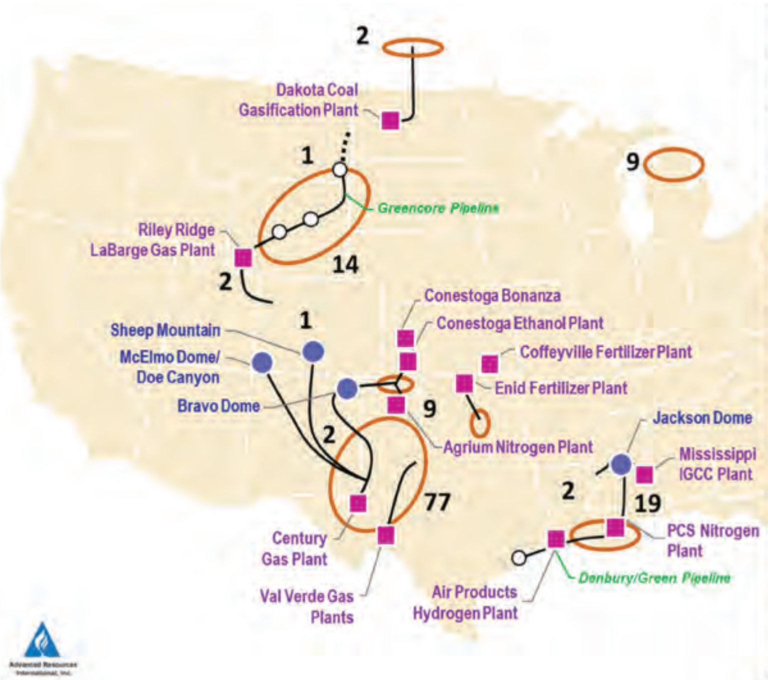
Available formations for storage and cost (see Figure 2 and 3) need not limit deployment of CCUS. Capture and processing of the CO_2 must be matched to the EOR or storage site in order to maximize the business case. Location could be a limiting factor in the broad opportunities for EOR, but experience in the Permian offers an optimistic outlook for the potential of CCUS, the integration of a pipeline delivery system to multi-site locations, and the use of 45Q to address the overall cost of capture and delivery.

Steve Melzer, president of Melzer Consulting, noted several examples of investments and CO2/EOR tests, suggesting the expansion of 45Q has spurred significant investor interest in the Permian. With the clear potential for even more expansion in Permian ROZ, 45Q is providing a monetizable mechanism for investors and project participants. ROZ resources have been estimated to represent a doubling or more of oil production potential in the Permian and can open vast opportunities for growth and energy security long term by employing CCUS.

Yet challenges remain. These include both transporting the oil that is produced in the West Texas oilfields to refining centers along the Gulf Coast and transporting the CO_2 to the target zones for EOR or storage.

In addition, the Permian fields, conventional and unconventional, have other challenges, including water use, water disposal and the need to develop and accommodate both sustainable operations and growth. Pipeline infrastructure for CO_2 deliveries is critical, but so too are pipelines to deliver crude oil to markets for refining.

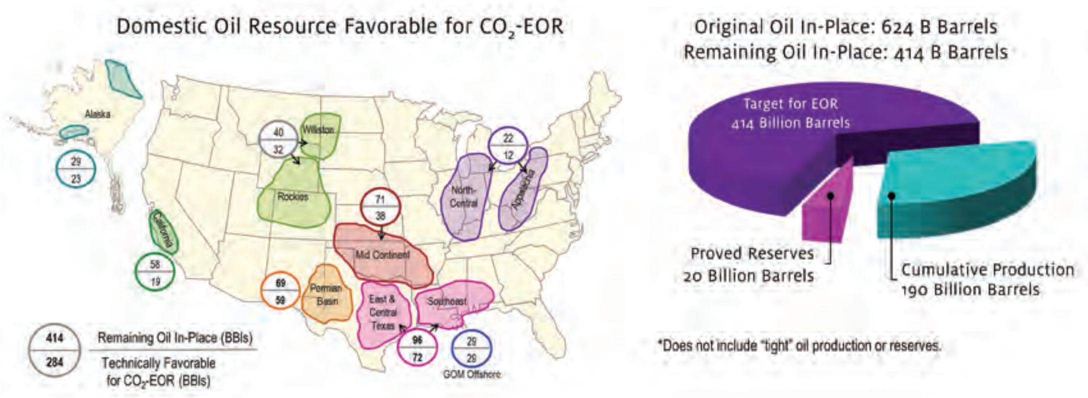
Figure 2: Current CO_2 EOR Operations and CO_2 Sources (2014-19)



Oil Production (2014)	
CO_2-EOR Projects	136
Oil Production (MBbl/d)	300
CO_2 Supplies (2019)	
Number of Sources	17
• *Natural*	*5*
• *Industrial*	*12*
CO_2 Supply (Bcf/d)	3.3
• *Natural*	*2.2*
• *Industrial*	*1.1*

Source: Advanced Resources International based on Oil & Gas Journal and other industry data, 2014-2019.

Figure 3: US Oil Resources Favorable for CO2-EOR and the Potential Impact on Conventional Oil Resources



Source: Advanced Resources International, 2018.

In short, CCUS investment and the use of 45Q in the Permian is expected to continue to grow, as will demands for advances in technology. Longer term, the Permian provides one of the largest sinks for CO2 utilization and EOR, as well as long-term storage. The key to short-term, wide scale deployment of CCUS will be progress and success in the Permian.

A CASE STUDY - BENEFITTING FROM REGIONAL PARTNERSHIPS

While the Permian will play a large role in near-term future adoption, Core Energy has used CCUS for over a decade in northern Michigan. Core Energy has extensive experience with the Battelle-led Midwest Regional Carbon Sequestration Partnership (MRCSP), one of seven regional partnerships established by DOE to assess the technical potential, economic viability and public acceptability of carbon sequestration.

Oil is produced from geologic reef formations in the region, and there is strong potential for increased oil production.

Core has accomplished one of the fundamental requirements for using 45Q – an IRS-approved measurement and verification plan to quantify the CO_2. Core officials report the working relationship with MRCSP assisted in building the necessary technical and commercial framework to safely and permanently store CO_2 in upstate Michigan.

The company has taken a dual approach to field development, seeking to capture value from both the oil produced from the EOR process and to consider the potential CO_2 storage value. Core began to implement the strategy even before the most recent 45Q revisions.

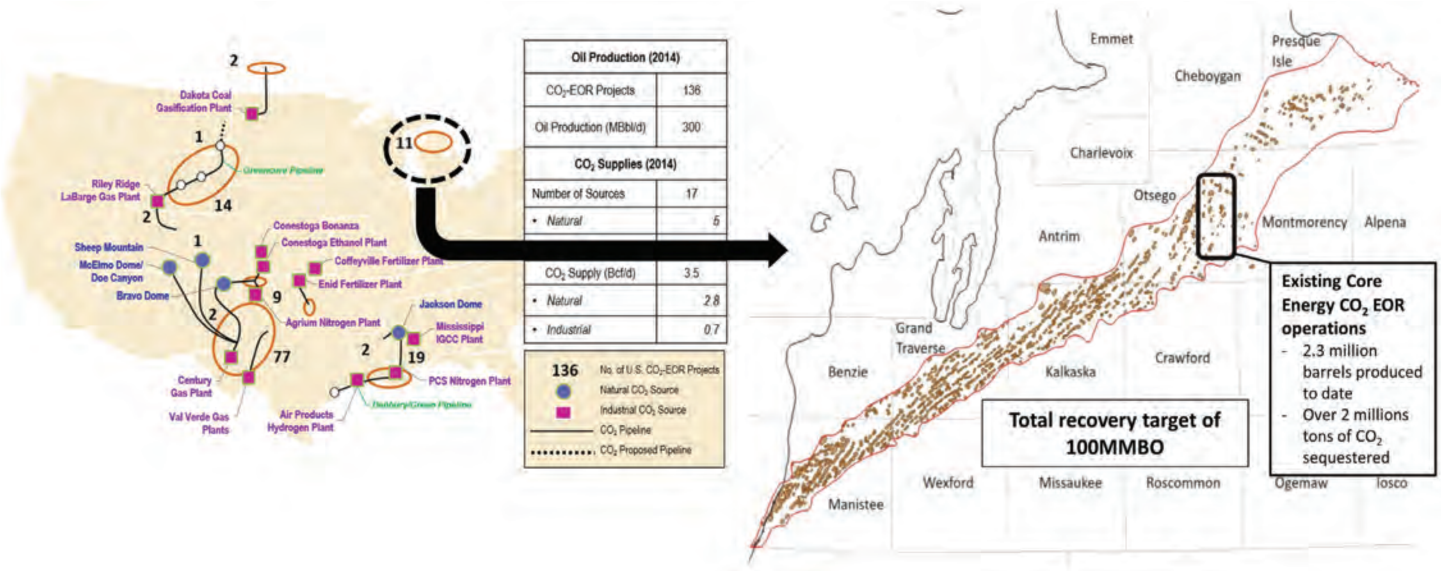
The technology and operations are in place and functioning. Core also developed a strategy to deal with the structure of 45Q, which requires the capture investor to have a tax appetite substantial enough to realize the value. That is, the value of the tax credits can't be realized unless the company balance sheet can accommodate such credits. This is a major challenge for many independent operators, which Core CEO Bob Mannes addressed.

"Our challenge has never been in the technical or transactional areas, but in the ability to form the tax equity partnership Core would require to realize the 45Q credits," he told the workshop audience. Core was simply not large enough to take advantage of the tax credits offered by the provision without using a tax equity partnership mechanism.

Independent operators want to participate in the CCUS marketplace, and 45Q is a strong enabler. The ability to realize commercial benefit is critical and will require further refinement.

Core Energy's experience provides a classic example of a business activity integrated into a community, bringing economic value through jobs and commerce that support the oil and gas industry while remaining aware of and responsive to the needs of citizens and the environment. It

Figure 4: Existing Operations of Core Energy in Michigan



Source: Core Energy, 2019.

also shows an O&G independent can be nimble enough to make the investments to capture CO_2, which enables the EOR step, which then creates the ability to use the 45Q credit, and still be limited because the company balance sheet doesn't meet the requirements to use the tax credits. That is likely to be an ongoing challenge for independent O&G operators.

Environmental concerns about CCUS are common but not insurmountable. Kurt Waltzer, managing director of the Clean Air Task Force (CATF), suggested ways to move forward.

CATF is a nongovernmental organization that advocates for technologies and policies that address environmental and climate needs. Among Waltzer's key points:

- CCUS can be seen as a necessary component to reduce emissions now and in the future, rather than as an enabler for the continued use of oil, coal and natural gas.
- The assurance of safe and permanent storage for CO_2 is fundamental to gaining support from nongovernmental organizations and environmental groups.
- CATF supports the opportunities presented by CCUS, but there is no universal consensus among nongovernmental organizations around CCUS or 45Q.

ANOTHER VIEW FROM REAL LIFE

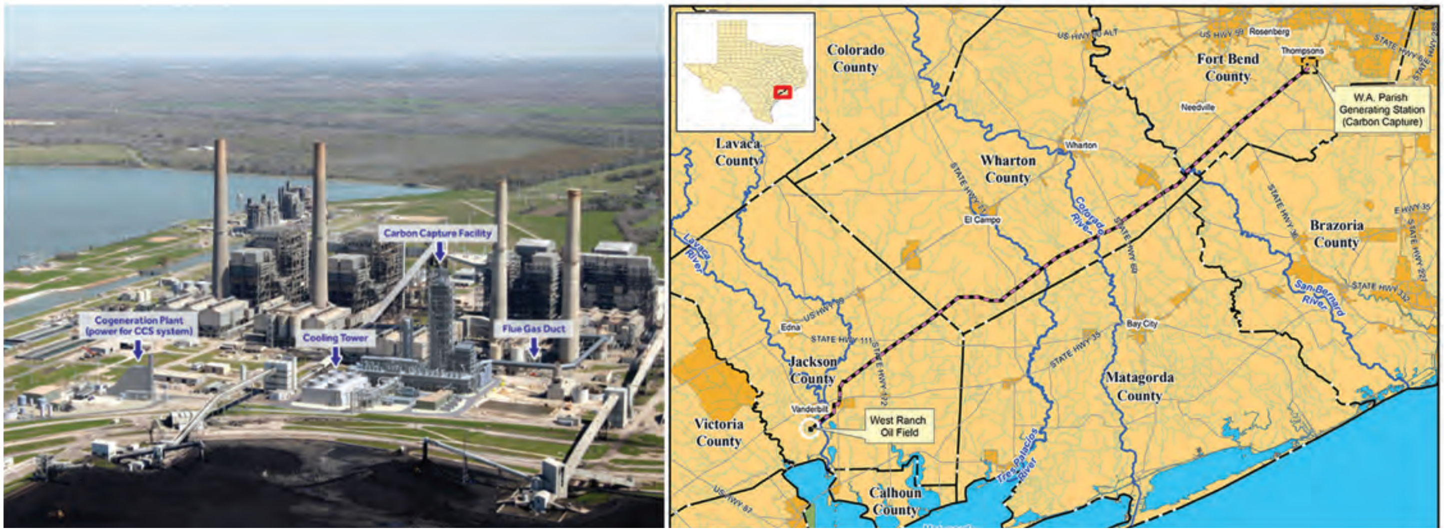
NRG's Petra Nova power plant outside of Houston is capturing CO_2 and delivering it to the oil fields in South Texas. David Greeson, a former NRG executive and project lead for Petra Nova, acknowledged the challenges and shared some of the solutions the company has found.

The PetraNova project captures CO_2 from a coal-fired plant outside Houston, then uses it in South Texas.

According to Greeson, the structure of the Texas electricity market does not reward baseload generation, so carbon-free baseload power must compete with other generation, including that from renewable sources. Renewables are heavily subsidized, causing challenges for baseload coal and natural gas. That's an even greater challenge for a baseload coal or gas plant whose operators want to make the necessary capital investment for carbon capture. To recover the costs, the plant must run – and supply power to the grid – steadily. Ironically, carbon-free renewable generation is intermittent, suggesting the need for a market structure that instead rewards reliable 24/7 carbon-free generation.

The NRG project launched without the benefit of 45Q tax breaks; it did receive funding from DOE, accounting for less than 20% of total capital and startup costs.

Figure 5: PetraNova Carbon Capture Project located near Houston. TX



Source: NRG, 2017.

Key points:

- The uniqueness of a coal-fired power plant producing carbon-free power, available 24/7 without the traditional reliability concerns around other carbon free sources.
- Carbon-free power from fossil fuels should be considered a significant environmental and business opportunity, especially in global markets. The US can develop the technology and knowledge needed and export it to the rest of the world.

CCUS offers tremendous opportunities, but to play a meaningful role in solving the global climate challenge, it must be deployed beyond scattered projects.

Greeson suggested that is not an impossible burden. The technology is commercially available and has been demonstrated as a viable commercial option. The opportunities for successful and permanent storage remain largely untapped.

NEXT STEPS AND ROLE OF CCME AT UH

While there are opportunities for expanding carbon capture and utilization, especially with benefits from a restructured 45Q, it is clear that costs remain high. Some suggested changes to 45Q are detailed in the appendix and pose the opportunity to advance an aggressive path to decarbonize the energy industry.

The potential for increased revenues from EOR will help, as will the expanded role of 45Q, although the provision still has risks that remain unclear. Ongoing work from the National Petroleum Council and the Center for Carbon Management in Energy at UH will offer more insight in the future. The NPC study is expected to be completed by end of the year.

The CCME is dedicated to being a center of excellence for CCUS not only in the US but globally and will be committed to an academic-industry partnership to ensure relevance and impact for the technology, engineering, legal, policy and business fields.

These highlights from the conference offer strong evidence that carbon capture, utilization and storage will play an important role in the coming decades as global focus on reducing emissions grows. Federal tax policy can provide an important boost as technologies, policies and business practices evolve.

The following appendix offers a comprehensive look at the latest iteration of 45Q.

“The potential for increased revenues from EOR will help, as will the expanded role of 45Q, although the provision still has risks that remain unclear.”

APPENDIX

1. Economic Substance Doctrine.

Section 45Q serves an important goal of creating market incentives for private citizens to affirmatively take steps to sequester carbon oxide into secure geological formations. Without such a tax credit, sufficient financial incentives likely would not exist for citizens on their own to engage in such an expensive endeavor. Congress has recognized this fact through its design of section 45Q. For taxpayers who sequester carbon oxide as part of a tertiary recovery operation, Congress expressed a desire to provide a substantial (albeit reduced) amount of section 45Q credit.[5] The taxpayer in the tertiary injection context has sequestered carbon oxide, but at the same time that taxpayer has received another compensating benefit, namely enhanced recovery of oil and gas through the tertiary development operations. So, the amount of the tax credit afforded to the taxpayer under section 45Q is meaningful but objectively much less than the tax credit afforded to taxpayers who sequester carbon oxide in a secure geological formation outside of the tertiary development context.

Said differently, section 45Q provides taxpayers who sequester carbon oxide into a secure geological formation outside of the tertiary recovery context with a much higher tax credit amount.[6] The increased amount of tax credit for carbon sequestration where no tertiary recovery benefits are created makes sense because the sequestration of carbon oxide in the non-tertiary context necessarily means that the taxpayer will receive no anticipated revenue stream from that carbon sequestration activity. Carbon sequestration in the non-tertiary recovery context necessarily means that the taxpayer will incur solely financial costs to capture the carbon and to sequester it as the taxpayer will not receive any offsetting revenue for storing the carbon oxide molecules, given that no enhanced recovery of a commercially marketable product (namely enhanced oil and gas recovery) arises in that context. Thus, the entirety of the financial incentive for engaging in carbon sequestration in the nontertiary scenario arises solely from the tax benefit of the allowable section 45Q credits, and Congress tacitly recognized this fact because it gave a larger tax credit benefit to motivate taxpayers to engage in carbon sequestration in that context and necessarily needed to do so as that activity does not create or produce a marketable product (namely no enhanced oil or gas is recovered in that context). The design of section 45Q, therefore, makes perfect sense in terms of its calibration of the tax credit benefit to motivate taxpayers to engage in activities that promote climate mitigation policies that Congress wants to promote in a broad range of contexts. But even so, section 45Q's unique design features require the Treasury Department and the IRS to carefully consider how section 45Q's goals should be meshed with generally applicable federal tax principles like the economic substance doctrine.

In 2010, Congress codified the judicially created economic substance doctrine through the enactment of section 7701(o).[7] The judicially created economic substance doctrine provides the government with broad authority to disregard the tax benefits derived in transactions that have no economic substance apart from the tax benefits derived from engaging in the transaction.[8] In relevant part, section 7701(o)(1) provides that in the case of any transaction to which the economic substance doctrine is relevant, such transaction shall be treated as having economic substance only if the transaction changes in a meaningful way (apart from Federal income tax effects) the taxpayer's economic position and the taxpayer has a substantial purpose (apart from Federal income tax effects) for entering into such transaction. The above broad-based economic substance doctrine serves a legitimate purpose of preventing tax motivated transactions that frustrate Congress' desires.

But, application of that doctrine in the context of section 45Q would serve to frustrate Congress' desires, not promote them. In this regard, in the context of an allowance of the section 45Q tax credit in the context of nontertiary sequestration as envisioned under section 45Q(a)(3), there is no other derived financial benefit from the carbon sequestration activities apart from the federal income tax credit benefits afforded by section 45Q. The non-tax benefits for engaging in carbon sequestration are benefits derived by the society at large in the form of the positive climate change benefits derived from removing ambient carbon oxide from the atmosphere. This societal benefit is the substantial purpose that Congress sought to further through its enactment

and later expansion of the section 45Q tax credit, but as to the particular taxpayer engaged in the relevant carbon sequestration activity this societal benefit represents "an externality" as the taxpayer receives no direct financial benefit in the nontertiary storage context apart from the allowance of the tax credit for engaging in the carbon sequestration activities.

Thus, an important initial question for an appropriately functioning tax credit under section 45Q relates to when and to what extent will the economic substance doctrine be called upon to disallow tax benefits attributable to carbon sequestration activities that by their very nature are conducted solely to obtain the tax benefits of section 45Q. Section 7701(o)(5)(C) states that the determination of whether the economic substance doctrine were relevant to any particular transaction is to be made in the same manner as if section 7701(o) had never been enacted. Thus, if the economic substance doctrine was not relevant to a particular activity or investment prior to the enactment of section 7701(o), the IRS has recognized that it is still not relevant after the enactment of section 7701(o).[9]

Nevertheless, at present, the government has stated that the determination of when to apply the economic substance doctrine is to be done on a case-by-case basis, depending on the facts and circumstances of each individual case.[10] Moreover, the IRS has a ruling policy that it will not provide private rulings on the question of whether or to what extent the economic substance doctrine is relevant to a particular transaction.[11] Thus, at present, taxpayers who cannot meet the profit-motivation safe harbor indicated in section 7701(o)(2) are left with a significant level of uncertainty as to the manner and the extent to which the economic substance doctrine might be used to disallow tax credit benefits derived from carbon sequestration activities when the tax benefits of those activities are the principle reason the taxpayer was motivated to engage in carbon sequestration in the first place. In thinking about this issue, the Treasury Department and the IRS need to ensure that the application of generally applicable tax principles like the economic substance doctrine do not frustrate the goals of section 45Q or else taxpayers will not obtain the tax benefits that are necessary to motivate them to engage in the positive climate change mitigation efforts that Congress seeks to motivate them to conduct.

The Treasury Department and the IRS, therefore, need to provide guidance to indicate that the economic substance doctrine is not relevant to activities that are conducted under the auspices of section 45Q and then need to state that the generally applicable economic substance doctrine would not be used as a basis to disallow the availability of tax credits otherwise allowable under section 45Q. Clarity is needed because the economic substance doctrine is an otherwise far-reaching doctrine that if applied to the section 45Q context would frustrate the Congressional intent to provide an explicit tax subsidy to motivate private citizens to engage in carbon sequestration activities that would not otherwise be pursued "but for" the allowance of the section 45Q tax credits. The legislative history to section 7701(o) provides significant support for the Treasury Department to provide the clarity along the lines advocated in this comment letter as the following explanation of the relevance of the economic substance doctrine makes plain:

> If the realization of the tax benefits of a transaction is consistent with the Congressional purpose or plan that the tax benefits were designed by Congress to effectuate, it is not intended that such tax benefits be disallowed. . . Thus, for example, it is not intended that a tax credit (e.g., section 42 (low-income housing credit), section 45 (production tax credit), section 45D (new markets tax credit), section 47 (rehabilitation credit), section 48 (energy credit), etc.) be disallowed in a transaction pursuant to which, in form and substance, a taxpayer makes the type of investment or undertakes the type of activity that the credit was intended to encourage.[12]

Section 45Q is not listed in the above non-exhaustive list of examples of where Congress' desire to promote some other policy goal would be subverted by the application of the economic substance doctrine. But, section 45Q provides an even clearer case for not applying the economic substance doctrine than several of the illustrative areas cited in the legislative history to section 7701(o) because section 45Q(a)(3) provides a tax benefit for an activity where no other financial gain is posited to exist apart from the tax credit

> "Congress' allowance of a higher tax credit in the context of carbon sequestration into a non-tertiary formation provides tangible evidence of Congress' desire to motivate taxpayer behavior even when there is no other financial benefit in the carbon capture and sequestration context."

benefits, and so this reality makes section 45Q a unique provision to which general tax principles must recognize as exceptional.

Guidance is needed in regulations because recent private rulings issued by the IRS evidence a reluctance by the agency to disclaim the relevance of the economic substance doctrine in situations where Congress' goals would seem to be frustrated by its application. In this regard, the IRS has on multiple occasions reserved on the issue of whether investments that generate tax benefits under the analogous area of section 45 implicated the economic substance doctrine even though section 45 is cited as an illustrative example for where the economic substance doctrine should not be applicable.[13] The IRS's refusal to rule on the applicability or nonapplicability of the economic substance doctrine was left unexplained in those private rulings, and that's a problem. Consequently, in the context of this current regulatory project, the Treasury Department and IRS need to explicitly make clear that Congress' desire to encourage carbon sequestration activities solely or principally for tax reasons is what Congress envisioned and so by necessity the economic substance doctrine is inapplicable to activities conducted under the auspices of section 45Q. Again, Congress' allowance of a higher tax credit in the context of carbon sequestration into a non-tertiary formation provides tangible evidence of Congress' desire to motivate taxpayer behavior even when there is no other financial benefit in the carbon capture and sequestration context. Thus, given this reality, the economic substance doctrine cannot be applied in the carbon sequestration context as doing so would frustrate Congress' goal of using the tax system to provide the principal or sole financial incentive for taxpayers to engage in the carbon sequestration activities that otherwise would not be financially viable apart from the tax benefits.

Thus, forthcoming guidance by the Treasury Department should indicate that taxpayers who make investments in carbon capture equipment and then use that carbon capture equipment to sequester the captured carbon oxide will be entitled to a tax credit under section 45Q and will be treated as being engaged in the active conduct of a trade or business regardless of whether or not those carbon sequestration activities ever generate a financial profit apart from the tax benefits derived from the tax credit allowed under section 45Q. In order for Congress' goals to promote carbon sequestration to be realized, forthcoming regulations should make plain that the ongoing cost associated with the conduct of these carbon sequestration activities should be deductible under section 162 and then should make plain that the ability to claim a tax credit under section 45Q will not be disallowed by reason of the economic substance or business purpose doctrines as long as those carbon capture and sequestration activities are actively conducted in the manner Congress desired to promote through the enactment of section 45Q. Applying the business purpose doctrine and the economic substance doctrine in the context of carbon sequestration activities would frustrate the fundamental policy goals that section 45Q was designed to promote.

2. Secure geological storage.

For both section 45Q(a)(3) and (4), the captured carbon must be sequestered into a secure geological formation. Section 45Q(f)(2) provides that the Treasury Department, in consultation with the Administrator of the Environmental Protection Agency, the Secretary of Energy, and the Secretary of the Interior, shall establish regulations for determining adequate security measures for the geological storage of qualified carbon oxide. In furtherance of that regulatory directive, Sec. 3.01 of Notice 2019-83 specifically asked for comments on two matters:

- Are there technical criteria different from or in addition to those provided in the EPA's GHGRP that should be used to demonstrate secure geological storage? Are there existing guidelines, standards, or regulations that could be used to demonstrate secure geological storage such as those developed by the International Organization for Standardization (ISO)?
- Should EPA's GHGRP rules continue to be the reporting requirements for purposes of § 45Q, and should an approved MRV Plan from the EPA be received before any §45Q credit can be claimed? Are there any viable alternatives to the subpart RR reporting requirements, such as third party, Department of Energy, or State certification?

As to the first bulleted item, we believe that the government should be open to standards developed by the International Organization for

Standardization.[14] We believe that the IRS and EPA should not foreclose the opportunity to be certified by a nongovernmental organization such as ISO.

However, the caution we would like to provide to the Treasury Department and the IRS is that the science is quickly evolving in this arena. Significant discoveries and learning are occurring in terms of carbon sequestration and carbon capture. As a result, any regulatory guidance in this area should not be static and should recognize that best practices and standards are going to evolve. Given this reality, forthcoming regulations should allow certification of a formation as "geologically secure" under safe harbor provisions but then should provide a means to satisfy that criteria under a facts and circumstances test through certification by the EPA, an appropriate state government authority, or through a rigorous nongovernment organization such as the ISO certification process. The regulatory grant of authority under section 45Q(f) is broad, and the Treasury Department should exercise its broad authority under section 45Q(f) to ensure that its regulations provide clarity on what will be considered a secure geological formation but then provide a facts and circumstances test that could be utilized for potential future developments.

As to the second bulleted item, we recognize that the Treasury Department has a legitimate concern that adequate proof should exist that the sequestered carbon oxide has been appropriately secured before a tax credit is allowable under section 45Q. The Treasury Department also is right to understand that other agencies or nongovernmental organizations are likely better positioned to address the specific technical issues related to whether the captured carbon molecules have been stored in a secure geological formation. However, even though the Treasury Department and the IRS need administrable regulations on issues outside of its areas of particular expertise, the regulations nevertheless should take a balanced approach. As long as adequate proof of sequestration into a secure geological formation exists, then the Treasury Department should not bar the allowance of a tax credit under section 45Q simply because of a procedural foot fault when the taxpayer has complied with the substantive directive to which section 45Q is aimed.

Thus, we believe that the government's disallowance of section 45Q tax credits in the fact pattern set forth in FSA 20183701f (May 3, 2013) is overly harsh if the facts in that ruling were such that the taxpayer could have demonstrated that the carbon dioxide had been sequestered into a secure geological formation. The fact that EPA had not pre-approved the taxpayer's sequestration plan as of the time of the taxpayer's filing of its tax return represents a "foot fault" that by itself should not bar the allowance of tax credits under section 45Q. To state that such proof must exist as of the time of the taxpayer's filing of the original tax return represents a procedural trap for the unwary that frustrates the legitimate goals of ensuring that a tax credit is provided to those taxpayers who in fact have substantively engaged in the activity that Congress desired to promote, namely the capture and sequestration of carbon oxide so that it does not become ambient. The intent of the statute and the public policy goal is to ensure that sequestered carbon oxide is placed in a secure geological formation. Certainly, confirmation from an agency with appropriate oversight should be obtained. However, conditioning the availability of the tax credit afforded under section 45Q upon the pre-approval by the EPA sets forth an extra compliance hurdle that potentially limits the tax credit benefits to taxpayers who have engaged in the activity that Congress desires to promote.

In our view, forthcoming regulations should provide a safe harbor that indicates that pre-approval from the EPA of the taxpayer's carbon sequestration plan and compliance with that pre-approved plan would provide certainty that the taxpayer's activities are compliant with section 45Q's substantive requirements, but that should not be the sole means of demonstrating compliance. Absent prior EPA approval of the taxpayer's carbon sequestration plan, the taxpayer should have the burden of proof to demonstrate that its captured carbon was sequestered into a secure geological formation under a facts and circumstances analysis. In this regard, the taxpayer should be given an opportunity to have a fact-finding by the EPA, state agency, or relevant nongovernmental agency to determine whether its carbon oxide molecules have been appropriately stored in a secure geological formation. If the taxpayer can satisfy this burden of proof under a facts and circumstances analysis that relies on the expertise of another agency, then the taxpayer

should be afforded with an opportunity for such a determination as doing so allows the taxpayer the opportunity to claim the tax benefits that Congress intended to provide.

3. Recapture of Tax Credit.

Pursuant to section 45Q(f)(4), taxpayers must recapture the benefit of any credit allowable under section 45Q(a) with respect to any qualified carbon oxide that ceases to be captured, disposed of, or used as a tertiary injectant in a manner consistent with the requirements of section 45Q.

In Sec. 3.02 of Notice 2019-32, the government asks for comments on the applicable standard that should be utilized to determine whether and to what extent a tax credit should be recaptured. In addition, the government asked for comments specifically on rules for the determination of whether a formation is a secure geological storage when carbon oxide is used as a tertiary injectant.

In our view, the recapture period should simply be the normal period for the statute of limitations for a tax return plus any extensions.[15] The existing limitations period that generally applies to tax returns already provides an appropriate balancing of interest between the taxpayer's desire for repose and the government's need for ensuring appropriate enforcement.

In terms of the standards for determining recapture, we note that the EPA is charged with oversight that includes the ongoing monitoring, reporting, and validation over whether carbon oxide has been captured and for determining whether the sequestered carbon oxide has ceased to be securely stored. Thus, the IRS should look to the EPA or, where appropriate, to a state agency charged with oversight over such facilities. The EPA or appropriate state agency with oversight over these formations should provide safe harbor guidance on the anticipated amount of carbon oxide that is likely to be re-released back into the atmosphere in a tertiary development project. Thus, once the EPA has certified that a formation is a secure formation and provided guidance on what amount of carbon oxide molecules is likely to be re-released in the context of tertiary activities, then that determination should be presumptively accepted pending contrary evidence provided either by the taxpayer, the EPA, or state agency that exercises oversight over the sequestration of carbon oxide.

However, notwithstanding the above safe harbor, the taxpayer should be able to provide scientific evidence to either the EPA or appropriate state regulatory agency to demonstrate that the amount of carbon oxide that has actually been re-released is less than what the EPA safe harbor guidelines anticipated for the taxpayer's tertiary activities. Thus, in our view, the regulations should provide a safe harbor to which taxpayers can rely and then provide a mechanism for taxpayers to demonstrate that the actual carbon oxide release was in fact lower than the safe harbor threshold.

4. Definition of Terms: Carbon Capture Equipment and Qualified Facility.

In Sec. 3.03 of Notice 2019-32, the government asked whether guidance is needed to further clarify terms and definitions appearing in section 45Q, such as carbon capture equipment, qualified carbon oxide, direct air capture facility, qualified facility, tertiary injectant utilization, or lifecycle greenhouse gas emissions.

We believe that clarification of these terms would be beneficial to both taxpayers and the government. In particular, the government should clarify the definition of "qualified facility" and "carbon capture equipment." A "qualified facility" is the industrial facility that is the source of the qualified carbon oxide and will often be owned by a party that is different from the taxpayer that will own the "carbon capture equipment." The IRS definition should understand that there is likely to be many different types of facilities and that facilities may have been retrofitted over time. The government should then make clear that the relevant party entitled to claim a tax credit under section 45Q is the taxpayer who owns the carbon capture equipment whether or not that party owns the qualified facility that emitted the carbon oxide.

5. Party Entitled to the Credit.

The reality for many arrangements is that multiple parties will be involved in the carbon sequestration process. Except in the case of the largest companies, it is likely to be the case that a carbon sequestration activity will include differing parties that perform one or more of the following functions: (a) one party will emit the carbon oxide at a qualified facility, (b) another party will invest in carbon capture equipment at that facility and will

separately own and operate that carbon capture equipment to capture carbon oxide molecules (hereafter referred to as the "Carbon Capture Partnership"), (c) a different party may agree to transport the sequestered carbon oxide molecules through its pipeline to a storage facility, and (d) a final party may own a storage facility and will take custody over the transported captured carbon oxide molecules and then inject those molecules into a secure geological formation.

Throughout each of these steps in the carbon capture and sequestration supply chain, contractual arrangements will likely exist that set forth the performance obligations of each party and the representations and warranties for each party in terms of its duty of care for ensuring that the captured carbon oxide molecules are not re-released back into the atmosphere. Investors into the entity that owns the carbon capture equipment may well be financial investors that provide the capital for the activities performed by the Carbon Capture Partnership but otherwise may be passive partners. Ownership of the carbon oxide molecules may well pass from the Carbon Capture Partnership to the next party in the supply chain indicated above. In other arrangements, the carbon oxide molecules may remain owned by the Carbon Capture Partnership throughout the transportation and/or injection process and the role of intervening parties may simply be to act as agents with respect to the transport and injection of the carbon oxide molecules for and on behalf of the Carbon Capture Partnership. And, with respect to the carbon oxide molecules that are transported to the injection site, the carbon oxide molecules may be commingled with other carbon oxide molecules that were captured elsewhere by a different Carbon Capture Partnership, and this commingling would necessarily occur if the carbon oxide molecules are placed into a common carrier pipeline for transportation to a common disposal site.

Forthcoming regulatory guidance needs to be nuanced enough to envision these expected and recurring business complexities but at the same time must also be transparent enough to be administrable for taxpayers and the government.

In Sec. 3.06, 3.07, and 3.09 of Notice 2019-32, the government requested comments on the following:

> .06 Under § 45Q(f)(3)(A), the credit is attributable to the person that captures and physically or contractually ensures the disposal, utilization, or use of the qualified carbon oxide as a tertiary injectant. The Treasury Department and the IRS seek comments on the types of contractual arrangements that investors anticipate with parties who capture or dispose or utilize qualified CO. What are common terms of contracts ensuring the disposal, utilization, or use of qualified CO as a tertiary injectant? What should result if such terms are determined to be insufficient?
>
> .07 What factors should be considered in determining the time and manner of the election under § 45Q(f)(3)(B) to transfer the § 45Q credit to a person that disposes of the qualified carbon oxide, utilizes the qualified carbon oxide, or uses the qualified carbon oxide as a tertiary injectant? If such an election is made, what issues should be considered regarding the transfer of the § 45Q credit?
>
> .09. Is guidance needed concerning structures in which project developers and participating investors would be respected as partners in a partnership generating a § 45Q credit? Further, is guidance needed on allocating the credit and recapture of the credit among the partners in a partnership?

We view each of the above three requests as presenting a common issue of what substantive requirements must be satisfied for a taxpayer to be entitled to the tax credit allowed under section 45Q, and so forthcoming guidance should designate one party in these complex supply chains that by default is entitled to the benefits of the tax credit afforded by section 45Q. We recognize that the government needs clear rules so that multiple parties do not submit competing claims of entitlement over the same section 45Q tax credit for the sequestered carbon oxide molecules. We also recognize that several parties in this supply chain have contributed significantly towards the ultimate sequestration of the capture carbon oxide molecules.

In our view, we believe that the government should provide clear guidance starting with when an investor into the Carbon Capture Partnership will be respected as a true partner and then

extends that guidance to identifying which party in the entire carbon sequestration supply chain is entitled to claim the section 45Q credits. We believe that such guidance should follow the below framework.

First, as to an investor's right to claim an allocable share of tax credits as a partner in a Carbon Capture Partnership that invests and operates carbon capture equipment, the government needs to provide guidance on when it will respect that financial investor's role as a partner in the Carbon Capture Partnership and when the government will claim that the financial investor is not entitled to be treated as a partner in the Carbon Capture Partnership. To begin with, there is a concern about whether a tax partnership can exist when no expected revenue is going to be generated from the Carbon Capture Partnership's activities. For situations where carbon capture equipment is constructed and operated and the eventual disposition of the sequestered carbon is into a nontertiary formation, the Carbon Capture Partnership will make capital investments into carbon capture equipment and then will incur costs to operate that equipment and then will likely have to pay other counterparties for the cost of transporting and disposing of the captured carbon oxide molecules. The Carbon Capture Partnership may have no revenues from these operations in the context envisioned by section 45Q(a)(3). The only financial benefit derived from the Carbon Capture Partnership in the nontertiary context is again solely the tax credits allowable under section 45Q.

The Supreme Court has indicated that the existence of a partnership for tax purposes depends upon a consideration of all of the facts and circumstances and a determination of whether the parties acted in good faith and with a business purpose to join together to conduct the business of the enterprise.[16] Unfortunately, the determination of whether a valid partnership arrangement exists is one where the courts have used differing tests.[17] For the government's part, the IRS has announced a fifteen factor test for determining whether a partnership is one that would be respected for tax purposes.[18] What is more, the Treasury Department has broad authority to disregard partnership transactions that violate the goals and purposes of subchapter K.[19] The government therefore needs to provide guidance on how a partnership that incurs only costs and does not expect to generate positive revenue nevertheless would be deemed to be a valid partnership that is engaged in an ongoing business for the purpose that Congress designed it to conduct. Congress wants to create a market for carbon capture activities and not simply apply a tax regime on an existing market that exists for nontax reasons. In important instances, section 45Q is attempting to create a market where none existed before. This reality has profound implications as to the manner in which general tax principles are to be applied in the unique context of section 45Q.

Second, as an additional issue, the government should also define what level of risk is necessary for an investor to possess in order to be respected as a partner in a Carbon Capture Partnership. In this guidance, the government needs to recognize that the Carbon Capture Partnership will receive contractual protections from the downstream counterparties who take over responsibility for transporting and disposing of the captured carbon oxide molecules and for its injection into a secure geological formation. Those contractual protections may also provide indemnity protection if the downstream counterparty fails to act in accordance with their contractual obligations. Those contractual arrangements may also include audit and inspection rights along with the right to receive documentation to indicate that the carbon oxide molecules were properly sequestered into a secure geological formation.

The government's successful litigation in *Historic Boardwalk Hall, LLC v. Commissioner*[20] creates concern over what residual partner-level risk must exist for an investor to be considered a partner in a partnership that conducts activities entitled to obtain a tax credit. In *Historic Boardwalk Hall, LLC v. Commissioner*, the government successfully disallowed rehabilitation tax credits otherwise allowable under section 47 that had been allocated to an investor in a partnership because the court found (at the government's urging) that the particular investor (Pitney Bowes) lacked a meaningful stake in either the success or failure of the underlying partnership activities and thus was not a bona fide partner in that endeavor; thus even though the underlying partnership had engaged in the rehabilitation activities that were intended to be incentivized by Congress, the benefits of the section 47 rehabilitation tax credits

were disallowed as the investor in that partnership had simply purchased tax credits and was not a bona fide partner with business risk. The IRS has cited its victory in *Historic Boardwalk Hall* as a basis to disallow monetization structures utilized in the context of section 45 production credits, claiming that the monetization strategies that were posited in the rulings had crossed a line so as to cause the investor to not be viewed as a partner with business risk but simply as an investor who had attempted to purchase tax credit benefits.[21] The investor, according to the government's audit position in those rulings, must be in form and substance a partner with an appropriate interest in the partnership's business activities in order to be entitled to claim the tax credits.

The government's victory in *Historic Boardwalk Hall* had a chilling effect on the tax credit market,[22] and so the IRS in Rev. Proc. 2014-12 provided a safe harbor for when it would not contest an outside investor's entitlement to claim tax credits as a partner in a partnership that conducts the credit-eligible activities.[23] Given that the government has already asserted that its litigating position in *Historic Boardwalk Hall* would be applicable to investors that seek tax credits outside the context of the tax credits that were the subject of that particular litigation, the Treasury Department should expand its safe harbor guidance set forth in Rev. Proc. 2014-12 to provide specific safe harbor guidance for section 45Q so that a partner's status as a partner in a Carbon Capture Partnership is respected and the allocation of tax credits to that partner would not be challenged. As part of that expanded guidance, in terms of making this safe harbor applicable to carbon sequestration, the government should provide affirmative guidance on what contractual protections can exist between the Carbon Capture Partnership and a party that is obligated to assume responsibility for transporting the captured carbon oxide and then to dispose of it into a secure geological formation. Specifically, the IRS should affirmatively state that a prohibited guarantee does not exist if the party responsible for disposing of the carbon oxide warrants that it did in fact dispose of the carbon oxide in a secure geological formation and agrees to indemnify the Carbon Capture Partnership if the EPA or another appropriate agency contests that determination. In a vast number of scenarios, it is unlikely to be the case that the Carbon Capture Partnership will own a secure geological formation. Thus, in many situations, the Carbon Capture Partnership will ask for assurances that the party that will inject the carbon oxide molecules does in fact own a secure geological formation. Contractual representations, warranties, and indemnities with respect to the status of the formation should not create a concern under Historic Boardwalk Hall, and forthcoming regulations should make this point plain.

Third, in terms of which party should be entitled to claim the benefits of section 45Q, we believe that forthcoming regulations should provide a default rule that the owner of the carbon capture equipment is the appropriate party to claim the tax credit under section 45Q. However, forthcoming regulations should allow the Carbon Capture Partnership to elect to transfer or assign some or all of the section 45Q credit in whole or in party to another party in the carbon capture supply chain if both parties make a joint election that is binding on both parties. The IRS should develop a form that would be attached to the tax returns of both parties that would set forth how the tax credit would be claimed by each of the parties, and the parties should be bound by the allocation set forth in the joint form. The joint filing of duplicate forms with tax returns of both of the relevant taxpayers would provide the IRS with the means to confirm that the transfer of any section 45Q credit to the other party was appropriate and each party consistently reports its share of the tax credits in accordance with the joint election. In our view, this assignment of credit should be an annual election. But importantly, absent a joint election to which the Carbon Capture Partnership joins in making, the Carbon Capture Partnership should be designated as the party that would be entitled to the full amount of the section 45Q credit under the default rule.

The above default rule and election procedure, in combination, would ensure that the Carbon Capture Partnership would be entitled to claim the tax credit allowable under section 45Q. The above framework would provide certainty under the default rule that the partners in the Carbon Capture Partnership would not be disgorged of the section 45Q credit absent the consent of the Carbon Capture Partnership. The ability to assign a portion of the section 45Q credits would allow other parties in the supply chain to obtain value for their participation and contribution without requiring that compensation to be in the form

“To be eligible for the section 45Q benefits, taxpayers must commence construction on qualifying projects before January 1, 2024.”

of cash. But having said all of this, the above framework also provides a clear and administrable framework for determining the party entitled to the credit and provides a mechanism to ensure that parties take consistent tax positions with respect to their share of the tax credit.

6. Beginning of Construction.

To be eligible for the section 45Q benefits, taxpayers must commence construction on qualifying projects before January 1, 2024. In Sec. 3.08 of Notice 2019-32, the government asks whether guidance is needed on what constitutes beginning of construction.

The Treasury Department and the Service have published extensive guidance on what constitutes the beginning of construction of a qualified facility under section 45(d). In the context of section 45(d), the government provided two tests for determining when construction of a qualified facility has begun.[24] Under the first test, the beginning of construction can be commenced by beginning physical work of a significant nature (Physical Work Test). Alternatively, under the second test, a taxpayer may establish the beginning of construction by meeting the safe harbor provided (Five Percent Safe Harbor). Both methods require that a taxpayer make continuous progress towards completion once construction has begun (Continuous Construction Test). In the section 45(d) context, the government supplemented these tests with a safe harbor (the Continuity Safe Harbor) that addresses what level of continuous activity must be met in order for construction to be viewed as ongoing.[25] In 2014, the government provided further clarifications to the Physical Work Test.[26] And, in 2015, the government extended the period for the Continuity Safe Harbor by an additional year.[27] Also in 2016, the government further modified the Continuity Safe Harbor and the Physical Work Test and provided that the Continuity Safe Harbor Test would be presumptively met if a facility is placed in service by the calendar year that is no more than four calendar years after the calendar year during which construction of the facility began.[28] In 2017, the government further modified the guidance it provided as to the Continuity Safe Harbor and modified other guidance as well.[29]

The above brief review of the government's guidance in the section 45(d) context demonstrates that the government has already expended considerable effort to set forth what constitutes the beginning of construction in an analogous tax credit situation. In our view, forthcoming regulations should simply rely on that existing guidance and extend that guidance to the section 45Q context. We commend the government for the diligence and detailed work it has already incurred in order to provide helpful and clear guidance for taxpayers.

However, we do note two areas where section 45Q should have differing guidance. In our view, the Continuity Safe Harbor should envision a longer period of time than just the four-year period specified in Notice 2016-31 when applied to section 45Q projects. The development of carbon sequestration equipment is ongoing and evolving, and prototypes are being developed and tested. Depending on the type and nature of the carbon capture equipment, these installation projects may be more extensive and require a longer construction period than would normally exist for a project contemplated under section 45(d). Thus, we would encourage the government to allow for a longer presumptive period under the Continuous Safe Harbor Test for a project constructed under the auspices of section 45Q than is currently envisioned in the section 45(d) guidance. As a second point, we think that the Continuity Safe Harbor Test should contemplate that a delay in a project due to the lack of an immediately available pipeline connection should be an excludible disruption in the context of a section 45Q project.[30] Carbon capture equipment will need to be connected to a pipeline that is capable of transporting the captured carbon oxide molecules to an injection site. The timing for construction and completion of pipelines might be subject to unexpected delays due to permitting and other matters that are outside the control of the entity that invests in the carbon capture equipment. Section 4.02 of Notice 2016-31 contemplates various excludible disruptions, and that guidance should be expanded to include delays or disruptions in construction caused due to the lack of an immediately available pipeline connection.

FOOTNOTES

1 – See enacted by § 115 of the Energy Improvement and Extension Act of 2008, Division B of Pub. L. No. 110-343 , 122 Stat. 3765, 3829 (October 3, 2008).

2 – See § 1131 of the American Recovery and Reinvestment Tax Act of 2009, Division B of Pub. L. 111-5 , 123 Stat 115 (February 17, 2009).

3 – See § 41119 of the Bipartisan Budget Act of 2018, Pub. L. No. 115-123 (February 9, 2018).

4 – See §45Q(f)(6).

5 – See §45Q(a)(4); §45Q(b)(1)(A)(i)(II). The IRS provided set forth a table for the amount of the credit applicable to each year for purposes of section 45Q(a)(4) in Notice 2018-93, Sec. 3, 2018-51 I.R.B. 1041. The amount so established by year is also subject to indexation for inflation after 2026. See §45Q(b)(1)(A)(ii)(II).

6 – See §45Q(a)(3); §45Q(b)(1)(A)(i)(I). The IRS provided set forth a table for the amount of the credit applicable to each year for purposes of section 45Q(a)(3) in Notice 2018-93, Sec. 3, 2018-51 I.R.B. 1041. The amount so established by year is also subject to indexation for inflation after 2026. See §45Q(b)(1)(A)(ii)(I).

7 – For an more in depth consideration of the codification of the economic substance doctrine and its impact on the decided case law, see Bret Wells, Economic Substance: How Codification Changes Decided Cases, 10 FLORIDA TAX REV. 411 (2010).

8 – See e.g., See Coltec Indus., Inc. v. United States, 454 F.3d 1340 (Fed. Cir. 2006).

9 – See Notice 2010-62, 2010-40 IRB 411.

10 – See Notice 2014-58, 2014-44 I.R.B. 746.

11 – See Rev. Proc. 2019-3, Sec. 3.02, 2019-1 IRB 130.

12 – See Staff of the Joint Committee on Taxation, Technical Explanation of the Revenue Provisions of the "Reconciliation Act of 2010," as Amended, in Combination with the "Patient Protection and Affordable Care Act" (JCX-18-10, 2010), at 152, n.344.

13 – See PLR 20110500 (Feb. 4, 2011) (IRS refused to rule on whether or to what extent the economic substance doctrine was implicated by the taxpayer's investment in refined coal investment project that was eligible for tax credits under section 45(c)(7)); PLR 201105006 (Feb. 4, 2011) (same); PLR 201105002 (Feb. 2, 2011) (same).

14 – See International Organization for Standardization, Carbon dioxide capture, transportation and geological storage — Carbon dioxide storage using enhanced oil recovery (CO2-EOR), ISO/FDIS 27916 (2018).

15 – See §6501(a).

16 – See Commissioner v. Culberton, 337 U.S. 733 (1949).

17 – See Bradley T. Borden, The Federal Definition of Tax Partnership, 43 HOUS. L. REV. 925 (2006).

18 – See Rev. Proc. 2002-22, 2002-1 C.B. 733.

19 – See Treas. Reg. §1.701-2.

20 – See Historic Boardwalk Hall, LLC v. Comm'r, 694 F.3d 425, 462–63 (3d Cir. 2012).

21 – See TAM 201729020 (July 21, 2017) (concluding that the parties structured a financial transaction in which Taxpayer facilitated the improper sale of §45 tax credits to an investor with the consequence that the Investor was not entitled to claim the tax credits arising from partnership's activity).

22 – See Richard M. Lipton, New Rehabilitation Credit Safe Harbor—Limiting Historic Boardwalk Hall, 120 J. Tax'n 128 (March 2014).

23 – See Rev. Proc. 2014-12, Sec. 4, 2014-1 C.B. 415.

24 – See Notice 2013-29, 2013-1 C.B. 1085.

25 – See Notice 2013-60, 2013-2 C.B. 431.

26 – See Notice 2014-46, 2014-2 C.B. 520.

27 – See Notice 2015-25, 2015-1 I.R.B. 814.

28 – See Notice 2016-31, 2016-1 C.B. 1025.

29 – See Notice 2017-04, 2017-4 I.R.B. 541.

30 – See Notice 2016-31, Sec. 4.02, 2016-1 C.B. 1025.

About the Center for Carbon Management

CCME

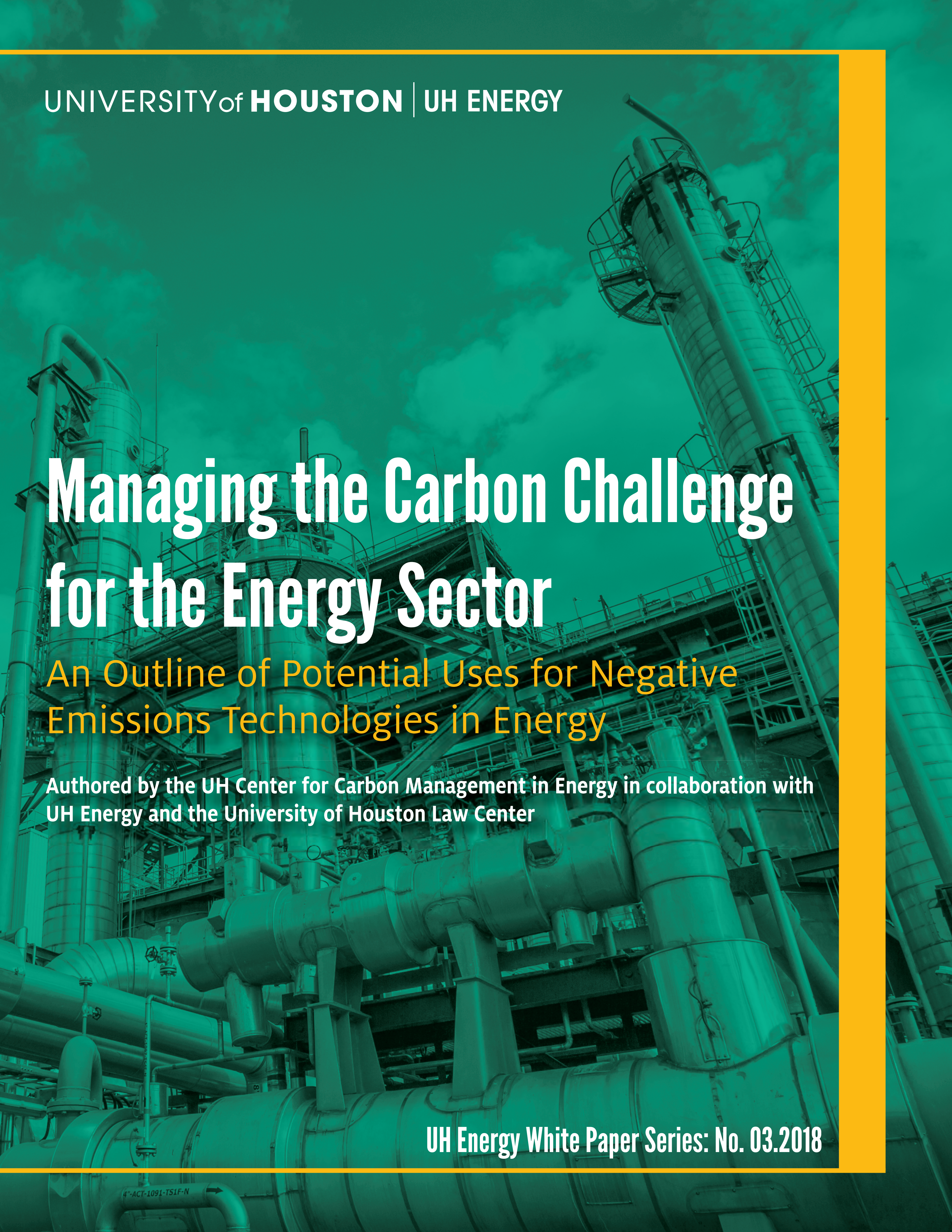
The Center for Carbon Management in Energy (CCME) is a collaboration across UH led by the UH Law Center and UH Energy that has the capability and capacity at the University of Houston to meet the lower carbon future energy transition challenges. Multi-disciplined, collaborative research from the required fields of engineering and science, business, law, public policy, as well as education for the marketplace, will be strategically aligned with our industry advisory board to address the needs of oil and gas, petrochemicals, and electric power markets. The principal investigators for the CCME are Ramanan Krishnamoorti and Tracy Hester.

The CCME will engage directly with these marketplace challenges to reduce carbon emissions that impact the climate and in doing so provide an accretive pathway for investment in the energy transition. We believe we are uniquely situated in Houston, aligned with our university energy advisory members, and purposely linked to global external collaborators, to impact the marketplace and provide the required solutions for the future.

CCME

Center for Carbon Management in Energy

APPENDIX B



UNIVERSITY of HOUSTON | UH ENERGY

Managing the Carbon Challenge for the Energy Sector

An Outline of Potential Uses for Negative Emissions Technologies in Energy

Authored by the UH Center for Carbon Management in Energy in collaboration with UH Energy and the University of Houston Law Center

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He was inducted into the American College of Environmental Lawyers in 2015, and named to its Board of Regents in 2018. He was elected as a member of the American Law Institute in 2004, and he was named the Top Environmental Lawyer in Houston in 2011 by Best Lawyers of America. He was also elected to the Council of the American Bar Association's Section on Environment, Energy and Resources (SEER) in 2011-2016, and he currently co-chairs SEER's New Law Professors Committee. Prof. Hester is past chair of SEER's Environmental Enforcement and Crimes Committee, and he is currently vice-chair of the Special Committee and Congressional Relations and its Greater Houston Partnership's Environmental Policy Advisory Committee.

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EXECUTIVE SUMMARY

With little fanfare or public attention, negative emissions technologies (NETs) have grown into a key element of international and domestic strategies to combat the increasing concentration of atmospheric carbon dioxide (CO_2) and climate change. In particular, the vast majority of models which identify successful pathways to attain the Paris Agreement's 2˚ C goal (much less the more ambitious 1.5˚ C target adopted recently) relies heavily on negative emissions technologies. Even if mitigation efforts drastically reduce ongoing and future emissions of greenhouse gases, current concentrations of CO_2 in the atmosphere from past industrial activities would result in dangerous anthropogenic climate effects for centuries, if not millennia, into the future. While mitigation of ongoing emissions and adaptation to climate change impacts remain indispensable, negative emissions technologies offer an important strategy to reduce these existing accumulations of CO_2 in a timespan relevant to human wellbeing.

The potential use, integration and impact of negative emissions technologies within the energy sector, however, remain largely unexplored. Energy producers, both globally and in the United States, face increasing challenges to the central role of fossil fuels in their current business models, including attempts to limit the production and use of fossil fuels, to require limits on emissions of greenhouse gases from energy generation units, or force restatements of reserves to reflect the risk of "stranded assets" of carbon-based fuels. The development and deployment of commercially viable negative emissions technologies could therefore provide an important tool for the energy industry to manage its own greenhouse gas emissions and offset emissions from the use of its products that are otherwise difficult or impossible to control.

On September 14, 2018, the University of Houston hosted a workshop to evaluate the feasibility and aspects of integrating negative emissions technologies as a component of energy production strategies. The attendees evaluated both the technical aspects of incorporating negative emissions technologies into energy systems as well as the potential governance options that they might create in the near future. The workshop then concluded that negative emissions technologies could play an important role in the future strategy and business models for energy production, refining, and fuels distribution. Integrating these technologies into the industry, however, will require substantial additional research, careful attention to establishing a rationale economic system to incentivize negative emission operations, building a sufficient market or sequestration capacity to manage CO_2 and greenhouse gases captured by negative emissions facilities, managing potential conflicts arising from natural resource demands and land use challenges, and assuring sufficient transparency and public input to meet current standards for corporate social responsibility and sustainability practices in the energy sector.

BACKGROUND

Sudden Prominence of NETs

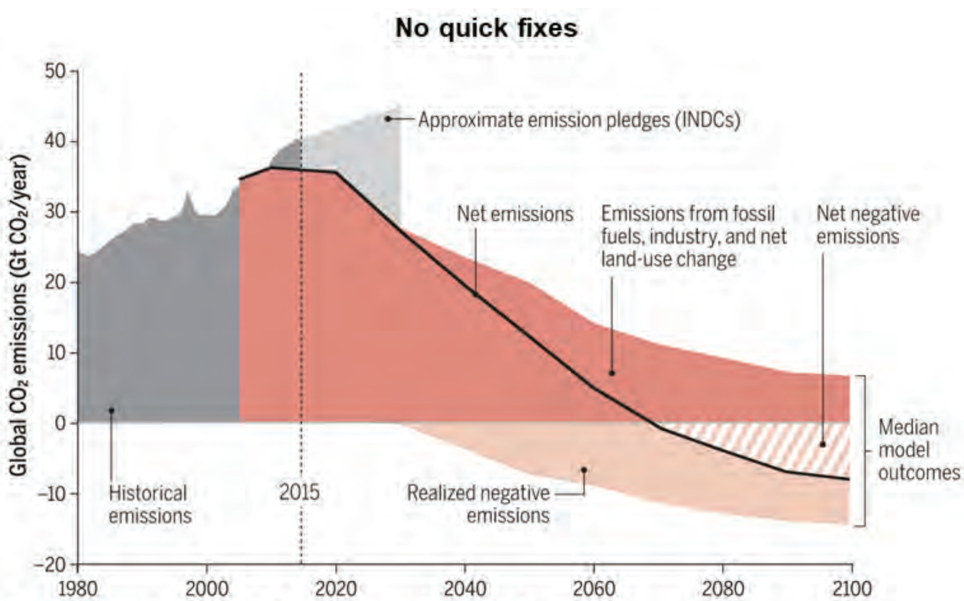
Negative emission technologies (NETs) are techniques that remove more CO_2 (or other greenhouse gases) from the ambient atmosphere than they emit. This broad definition includes strategies ranging from accelerated weathering, biochar, biological energy with carbon capture and sequestration (BECCS), afforestation, ocean iron fertilization, and direct air capture (DAC), each of which is described in greater detail in the Appendix. While these technologies adopt a broad array of approaches, each one seeks to absorb and utilize (or sequester) more greenhouse gases than it emits when evaluated over its entire lifecycle. For multiple reasons — including moral hazard concerns[1] and the relatively high costs, resource demands, accompanying negative environmental impacts, and possible land use conflicts of early iterations of NETs[2] — these technologies have received comparatively little attention in prior discussions over climate change options and policies.

Several trends point to the need for negative emissions technologies to respond to disruptive climate change. Fundamentally, the current elevated concentrations of CO_2 in the ambient atmosphere reflect over a century of anthropogenic emissions, and they will not readily drop even if current emissions dramatically decrease or completely cease. As a result, recent models that identify possible pathways which achieve the Paris Agreement's formal 2.0˚ C temperature target almost uniformly rely on negative emissions technologies.[3] Given the relatively slow reductions in emission rates of greenhouse gases, the need for negative emission technologies become even more pressing if the Paris Agreement parties hope to attain their more optimistic aspirational goal of 1.5˚ C.[4]

NETs and Energy

The U.S. energy industry, especially the utility electrical energy sector, the oil and gas exploration and production sector, and the refining sector, have not aggressively explored or implemented negative emissions technologies. While initial interest has focused on the use of carbon capture, utilization and storage (CCUS), particularly in conjunction with enhanced oil recovery, those technologies in their current forms

> "Fundamentally, the current elevated concentrations of CO2 in the ambient atmosphere reflect over a century of anthropogenic emissions, and they will not readily drop even if current emissions dramatically decrease or completely cease."



Kevin Anderson, and Glen Peters Science 2016;354:182-183

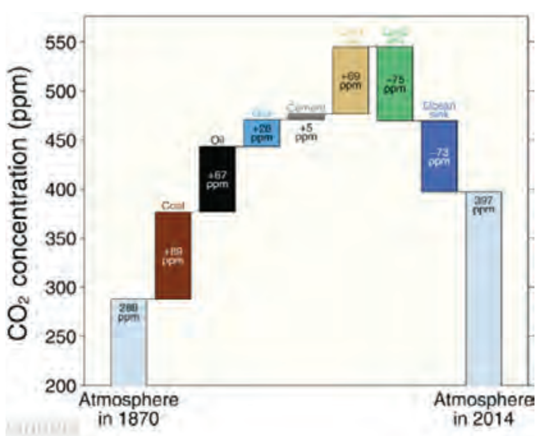
predominantly act as carbon-neutral platforms to capture new emissions at their point of generation. Rather than reduce existing concentrations of ambient greenhouse gases, CCUS therefore prevents the emission of additional CO_2 when producers burn or refine fossil hydrocarbons to generate electricity, fuels, or petrochemical products.

As a result, the possible role of negative emissions technologies in the energy sector remains largely unexplored even as the potential need for them in the production of energy has grown. Energy producers, both globally and in the United States, face increasing challenges to the central role of fossil fuels in their current business models, including attempts to:

- Limit the production and use of fossil fuels;
- Constrain emissions of greenhouse gases from energy generation units;
- Impose mandatory offsets or netting of greenhouse gas emissions, including from niche market uses that are difficult to directly offset (e.g., aviation fuels);
- Force restatements of reserves to reflect the risk of "stranded assets" of carbon-based fuels; and
- Disrupt financing provided for capital investment to construct new manufacturing and energy production facilities.

The energy sector offers several facets of special importance to negative emissions technologies. First, the industry faces the dual challenge of managing the impacts of carbon restraints on both the value and usability of its feedstocks (in particular, reserves of fossil hydrocarbon resources) and on its ability to use this feedstock inventory to produce, refine, transport, and distribute its products. Limits on emissions from fossil fuel consumption in particular may lead to constraints on the ability of hydrocarbon producers to explore and produce from their existing holdings. For example, one recent study concluded that attaining a two-degree C target would limit future emissions of CO_2 to approximately 800 gigatons; this limit would bar the future use of 20 to 40 percent of current fossil fuel reserves.[5] Second, reductions in emissions of greenhouse gases during exploration, production, and refining of hydrocarbons may require an increase of five to 15 percent in existing energy company capital expenditure budgets for European energy companies.[6] These limits could force a substantial restricting of the electrical generation and hydrocarbon refining processes themselves. The energy sector is currently investing heavily on managing its emissions, which also makes reducing emissions a waste management issue. Finding viable ways to rather utilize and transform this challenge into a profitable revenue stream in a climate constrained world is likely where the industry will find the most value.

Moreover, the energy sector also must wrestle with the potential impact of carbon restraints on the marketability of their eventual commercial product. Several energy-intensive commercial sectors — including aviation, shipping, cement production, and steel — will pose special challenges to attempts to reduce their carbon emissions, and these limits will cause secondary effects on the energy supplies demanded by them. While electricity consumers typically only focus on greenhouse gas emissions caused by the generation (not use) of electricity itself, some instances of



load-following electricity may also prove difficult to decarbonize.

Renewables and waste heat utilization will potentially have a larger role to play for energy intensive NETs, and the latter could ease the intermittency challenges that could thwart large-scale penetration of renewables. However, like any complex process, a seamless integration will largely depend on where and how system boundaries are drawn, eventually helping to consolidate NETs while paving the way for a hydrogen economy. Although energy producers agree that learning by doing requires doing, the transition is and will continue to be difficult to monetize unless there are pathways to revamp carbon management as a service-driven model rather than a compliance-driven model.

Last, the energy industry is the only one of a few industrial sectors that can manage this task at the scale required (outside of BECCS), and perhaps it is the only one that can immediately create economic value for recaptured carbon by capturing, utilizing and storing it for further use.

Other than federal tax credits for the use of captured CO_2 in enhanced oil recovery or other geological sequestration, the U.S. government has offered relatively limited funding to support research into negative emissions technologies overall. The growing importance of negative emissions technologies in future climate policy has led for several calls to increase the amount of federal grants and support for this area, including a major report from the National Academy of Sciences in September 2018.[7] The corporate community and academic researchers have added their voices in support for greater research in this area. None of these recommendations, however, have resulted in expanded funding or policy direction to support research on negative emission technologies, and these recommendations also failed to emphasize the need for greater research on how these negative emissions technologies might directly relate to or affect the energy industry.

Emerging Technological Pathways

Negative emission technologies can fall into a broad array of different approaches and methods (see Appendix). To explore the potential role that some of them may play in the energy sector, the workshop focused on three negative emissions initiatives that recently progressed to field demonstrations: high-volume direct air capture with chemical sorbents to sequester or use ambient CO_2 as a feedstock, the capture of CO_2 with contact polymers through low-energy absorption enabled through evaporation of water, and the production of emission-free or net negative emission electricity by using compressed heated CO_2 in lieu of nitrogen and steam. Each of these approaches offers promising possibilities for broader use in energy production and use, but each one also faces daunting technical challenges to achieve necessary cost reductions, improvements in reliability, and scalability.

Direct Air Capture in Energy Production

Direct air capture typically uses technological process, frequently chemical, to remove CO_2 from the ambient atmosphere and use it as feedstock or permanently sequester it. These processes offer the promise of scalability and speed to remove substantial volumes of CO_2 with relatively compact facilities, but available technologies remain costly and untested at large scales. In a recent report, the National Academy of Sciences identified five private companies that have begun either a demonstration plant, pilot plant, or laboratory work on NETs that could scale up for significant operations. Three of those companies already have NET facilities in operation.[8]

In particular, direct air capture technologies can help capture ambient CO_2 while providing

feedstock for carbon neutral liquid fuels. Carbon Engineering, for example, currently captures CO_2 from the atmosphere in an industrial-scale setting. The process captures up to one megaton of CO_2 annually by running pressurized ambient air through a bed of aqueous potassium oxide sorbent that feeds continuously into a calcium caustic recovery step to regenerate the sorbent and release the CO_2. Carbon Engineering's process yields a stream of high-purity CO_2 that it can either sequester, dedicate to enhanced oil recovery, or turn into a liquid hydrocarbon fuel.

The industrial scale of this process offers several important advantages. First, it allows the capture of a significant amount of CO_2 at a facility with a relatively small footprint. By contrast, other lower-energy processes rely on gentler pressure gradients over a broader surface area, and as a result they require larger amounts of land or space (as described below). Second, because CO_2 mixes and disperses quickly into the ambient atmosphere, this process can capture gas at locations removed from emission sources or other industrial operations. This feature enables industrial direct air capture to locate in remote regions with access to desired resources or energy supplies, and as a result operators can avoid some of the land use resource conflicts that bedevil other negative emission technologies such as BECCS.

This approach, however, suffers from important constraints. The process needs substantial amounts of energy to compress ambient air, regenerate sorbent, and maintain operating temperatures. Additional steps, such as creating hydrocarbon fuel from the captured CO_2, require even more power. As a result, industrialized direct air capture requires careful design to keep its energy demands from causing more CO_2 emissions than the process itself captures from the air. To minimize this risk, a DAC facility that uses fossil fuels such as natural gas to power its process may route emissions from that power source to its captured air stream. The growing prevalence of decarbonized power can also reduce this risk.[9] Second, industrialized DAC, by necessity, relies on complex and expensive capital machinery for its operations. As a result, it can be more costly than other technologies on a levelized basis.

A pilot plant constructed by Carbon Engineering in Squamish, British Columbia has investigated the performance of these processes and recently yielded sharper cost data. According to Carbon Engineering, the facility has captured approximately one ton per day of CO_2. Based on the facility's capture rate of one ton per day of CO_2 since 2015 and the capital costs incurred to construct and operate the plant, this process captures CO_2 at a levelized cost ranging from $94 to $232 per ton. The design required 5.25 gigajoules of gas and 366 kilowatt hours of electricity per ton of captured CO_2 (or, alternatively, 8.81 gigajoules of natural gas). This data gives a sharper view of potential costs of DAC, which prior reports had estimated across a broad range from $50 to $1,000 per ton of CO_2. The process also requires 4.7 tons of water for each ton of CO_2 that it captures under normal operating and environmental conditions. While Carbon Engineering's cost figure for its captured CO_2 includes the value of this water, the availability of ready water resources may constrain the suitable locations for future sizable DAC operations.[10]

This data highlights some of the key promises and challenges for current DAC technology. In particular, these results support the feasibility of using captured CO_2 to generate liquid fuels (including aviation kerosene). This specific demonstration plant, however, also used natural gas to power the DAC process. While the facility recaptured some of its own CO_2 emissions, future iterations will likely need to find locations with abundant renewable energy or zero-emission energy sources. The cost of liquid fuels generated by the DAC

> "Each of these approaches offers promising possibilities for broader use in energy production and use, but each one also faces daunting technical challenges to achieve necessary cost reductions, improvements in reliability, and scalability."

process currently remains higher than current market prices for mass market consumer fuels.[11]

Capture of Carbon Dioxide Through Moisture-Swing Absorption

Rather than an intensive process to capture and provide large volumes of CO_2 at high purity through industrial infrastructure, an alternative approach captures ambient CO_2 with a polymer absorbent that entrains CO_2 when wet. The capture process relies on ambient air movement and energy from evaporation, and the impregnated polymer releases the CO_2 when immersed into water. The facility operator would remove the CO_2 from the water. The process yields CO_2 at lower concentrations than concentrated processes that use compressed air, industrial power sources, and higher temperature gradients, but it requires far less power and costs far less per ton. The CO_2-enriched air generated by this process can be used for agriculture, manufacturing, or other uses.

This technological strategy would allow the placement of units at multiple locations to absorb ambient CO_2, and then collect them on a periodic basis to remove the captured CO_2 for utilization for sequestration. If each unit could capture up to one ton of CO_2 per day, an effective deployment of 10 million air capture units per year combined with a lifespan of 10 years would result in a steady-state capture rate of 3.6 Gt CO_2/yr that would exceed current anthropogenic CO_2 emissions.[12] While this number appears daunting, it compares favorably with the total number of automobiles produced globally on an annual basis or other large-scale industrial activities. Such a large-scale deployment would require substantive public involvement and financial support, which one speaker at the workshop estimated could total 22 cents more per gallon of gasoline.

Low-energy absorption swing technology powered by ambient air movement and transpiration, however, would also pose downsides. For example, the pace at which it removes CO_2 is slower than other technological processes, it would require larger amounts of dedicated land space than compact energy-intensive DAC operations, it demands substantial amounts of water, and it offers no immediately apparent co-location benefits with other industrial operations (including energy production and distribution).

Production of Zero-Emission Electricity Using Compressed Carbon Dioxide

In addition to technology dedicated primarily to capturing ambient CO_2 or other greenhouse gases, other forms of negative emissions technologies can remove ambient CO_2 as a side-benefit apart from their primary production purposes. This type of dual-purpose technology could play a critical role in the power generation sector.

The workshop examined one possible method to generate electricity that would rely on compressed heated CO_2 to drive turbine generators rather than conventional steam. Such an Allam cycle power plant would work at far higher efficiencies than a steam turbine system because CO_2 undergoes phase changes to drive the turbine without suffering thermodynamic losses (enthalpic penalties) at the same level as water. As a result, the turbine generates a small stream of excess pure CO_2 that can serve for other industrial purposes, including desulphurization of sour natural gas. Given that up to 40 percent of natural gas located outside of North America is sour, relatively small amounts of pure CO_2 – e.g., one ton — could generate large amounts of sweet natural gas — 100 million BTU per ton. This cost-effective path to sweetening natural gas would speed conversion of existing coal-fired power units to natural gas. In addition, the pure CO_2 stream generated by the Allam cycle power plant could provide the feedstock (along with sufficient cost-effective supplies of hydrogen) to produce methanol as

liquid fuel.

A demonstration plant constructed by NET Power in Pasadena, Texas has successfully demonstrated the feasibility of the unit used to combust natural gas in a pure oxygen environment. The tests included both a five megawatt and a 50 megawatt thermal unit. Based on initial results, NET Power predicts that it will be able to produce hydrogen for a cost of 35 cents per kilogram (if the system uses sour natural gas). The Allam process also generates significant amounts of heat that a production unit could harness for other purposes.

Governance and Regulatory Policy
Despite the forecasted need to remove substantial amounts of CO_2 from the ambient atmosphere on an annual basis by 2100, current international and domestic laws and policies do not facilitate — or even address — the hurdles posed to creating this enormous technological task. The primary international legal agreements that pertain to climate change, including the Paris Agreement, only tangentially refer to the use of carbon sinks and reductions in anthropogenic emissions via offsets. Other international instruments may pose regulatory or liability risks which could discourage some methods of negative emissions technologies (e.g., the use of the London Convention and London Protocol to limit the use of ocean iron fertilization). Domestic laws also do not explicitly address or facilitate research into negative emissions technologies or their broad deployment. These regulatory and liability barriers could prove significant. For example, some methods of negative emissions technologies will need substantial commitments of land, water, or other resources to operate at a scale required by current climate forecasts. BECCS, in particular, would demand the acquisition of substantial amounts of land and water to support the crops that would provide the feedstock for bioenergy facilities. By some estimates, reliance on BECCS alone to meet negative emission targets set out by the Paris Agreement would consume up to 40 percent of available arable land on a global scale. Approvals for some types of negative emissions technologies, such as ocean iron fertilization, could prove lengthy and difficult, and the creation and operation of sizable reservoirs to store captured CO_2 would pose daunting liability and regulatory challenges. The siting of significant arrays of DAC facilities, the assessment of their potential environmental impact, and the management and disposal of residues from DAC operations could also require governmental oversight and approval.

CONCLUSIONS

The workshop participants saw a possible

role for negative emissions technologies in the energy sector, and several noted that the interest in such technologies had recently grown stronger by acknowledging that negative emissions technologies have garnered more interest in the last year than there has been in the last decade. Negative emission technologies could help the energy sector wrestle with several looming important challenges, including risks in stranded assets or capital investments, assisting the possible unavoidable extension of fossil fuel use during a transition to a low carbon energy economy, and assuring amelioration of climate change effects on a temporary basis if emissions overshoot the limits required to meet goals set out by the Paris Agreement or other international commitments.

Important questions remain, however, about how negative emissions technologies would be integrated into possible future methods of energy production. Most fundamentally, no economic market currently exists to create a recoverable value for CO_2 removed from the ambient atmosphere. Carbon pricing mechanisms and or market approaches can place a price on the emission of CO_2 into the atmosphere, and offset mechanisms in cap

“Establishing investment mechanisms, such as the Paris Agreement’s provisions for internationally transferable mitigation outcomes, could potentially act as drivers for this integration.”

and trade or taxation could allow this "price" to be applicable to CO_2 removed from the air, currently in the United States these market mechanisms are spotty in use, and not large enough to provide a price signal.

The creation of such a pricing mechanism, either directly for recovered ambient CO_2 or through incorporating the use of negative emissions technologies in pricing systems for new or ongoing point source emissions, would provide an extremely important step in encouraging the development and deployment of negative emissions technologies. Establishing investment mechanisms, such as the Paris Agreement's provisions for internationally transferable mitigation outcomes, could potentially act as drivers for this integration.

Second, a vast mismatch of scale exists between the amounts of historical and current emissions of CO_2 with the potential markets or economic uses of the captured CO_2. The capture of ambient CO_2 in meaningful amounts would create an enormous inventory of CO_2 that would far exceed the existing markets for other industrial gases. For example, even if all worldwide polyethylene demand was satisfied through captured CO_2, that market would consume only 1 percent of the captured gas.[13] One workshop participant noted that the mass of CO_2 currently emitted annually exceeds the amount of sand and gravel produced on a global basis. While this challenge exists for any use of negative emissions technologies, it would pose a special challenge for the energy industry because it accounts for the large majority of industrial emissions of CO_2 and other greenhouse gases.

Third, the use or sequestration of CO_2 captured by negative emissions technologies could offer potential benefits and competitive advantages to the energy sector. The knowledge developed through tests on carbon capture usage and sequestration at large industrial facilities will apply as readily to negative emissions facilities that collect ambient CO_2. As a result, the hydrocarbon exploration and production sector can draw on a ready baseline of knowledge about geologic reservoirs for sequestration from its prior work on fossil fuel development, and the refining sector can adapt its existing process expertise to the development of liquid fuels from captured CO_2.

Fourth, the use of negative emissions technology in the energy sector will need to navigate the conflicts created by natural resource demands (in particular, water consumption), siting and land use conflicts, and disposal of process residues and captured CO_2. The energy industry has great familiarity with these issues and can integrate its assessment of these concerns with its development of negative emissions capacity and infrastructure.

Last, the broad development and integration of negative emissions technologies into energy production will likely spark public concern and demands for transparency. The energy sector will need to adapt its current consideration of corporate social responsibility and social license to operate to accommodate public disclosure and input during the construction and siting of negative emissions facilities that will likely provoke special concerns, especially during the early stages of implementation when the public will be unfamiliar with the technology.

APPENDIX

AFFORESTATION:
Planting trees in an area that previously lacked them, typically on a systematic and sizable scale. By contrast, reforestation is restoring areas where trees have been cut down or degraded.

Uncertainties and Barriers: Land availability and suitability. Effect on crop yields, farmers, and agrarian economies. Water requirements.

BIOCHAR:
Biochar is a charcoal-like carbon material produced by the controlled thermal decomposition of organic materials such as wood, manure or leaves, in a low-oxygen environment and at relatively low temperatures. While this process mirrors the production of charcoal in many respects, biochar – unlike charcoal -- is primarily used as a soil amendment to improve soil functions and to reduce greenhouse gas emissions from biomass that would otherwise naturally decompose.

Uncertainties and Barriers: Availability and use of land to produce organic materials. Water demand. Duration of sequestration of carbon in biochar. Scalability.requirements.

BECCS:
Achieves net negative emissions from the integration of trees and crops with carbon capture and sequestration (CCS). As biomass grows, it draws CO_2 out of the atmosphere. This biomass is then burned in power plants to produce energy, and the facility then stores the resultant CO_2 emissions via CCS.

Uncertainties and Barriers: Competition with food crops and biodiversity conservation. Increased land and water usage. CCS storage capacity and location considerations. Financial and technological scale-out barriers.

BLUE CARBON HABITAT RESTORATION:
Marshes, mangroves, and seagrass beds act as natural carbon sinks by capturing CO_2 from the atmosphere and storing them. The carbon thus stored in coastal or marine ecosystems is known as 'blue carbon'. Blue carbon habitats are known to sequester carbon at a faster rate than forests.

Uncertainties and Barriers: Data on carbon sequestration rates, on-site storage, emission profiles, and cost uncertainties.

BUILDING WITH BIOMASS:
Using plant-based material for construction in a way that stores and preserves carbon for the lifespan of the building. For example, this technique can use timber and bamboo for structural elements, hemp and wool for insulation, and hemp-lime for walling. These biological materials provide an alternative to standard construction materials, including steel and concrete, which are typically carbon-intensive to produce. Natural materials have additional benefits such as the ability to regulate moisture and absorb pollution.

Uncertainties and Barriers: Lack of investment, certification, and expertise currently impede large-scale deployment. Current regulations for buildings and construction efforts conflict with required developmental support.

DIRECT AIR CAPTURE:
Pulls and captures CO_2 out of the ambient atmosphere. The removed CO_2 can then be buried underground or used in chemical processes to produce alternative products for commercial use.

Uncertainties and Barriers: Financial and technological scale-out barriers. Need for large supplies of carbon neutral power to assure that DAC processes remain carbon-negative over their entire life cycle. Potential water and land use conflicts, depending on the DAC technology selected.

OCEAN IRON FERTILIZATION:
Injecting nutrients, such as iron, into nutrient-poor marine regions can trigger a bloom of phytoplankton whose enhanced photosynthesis would absorb CO_2. This method could also decrease the amount of dimethyl sulfide that marine organisms release, which can alter the reflectivity of clouds and alter warming.

Uncertainties and Barriers: Environmental and transboundary concerns. Questionable effectiveness. Current cost estimates are considered incorrect by certain groups. Social accepta¬bility is low, and some nations classify the practice as oceanic dumping of wastes considered illegal under international conventions.

ENHANCED WEATHERING (Terrestrial and Oceanic):
Terrestrial: The process begins with rain, which is usually slightly acidic because it absorbs CO_2 from the atmosphere on its journey to the ground. The acidic rain reacts with the rocks and the soil that it lands on, gradually breaking them down and forming bicarbonate in the process. Eventually, this bicarbonate washes into the oceans, where the carbon is locked up in the sea floor. Enhanced weathering accelerates this process by spreading crushed silicate material onto large surfaces.

Oceanic: The process proposes adding chemical carbonates to ocean waters to theoretically increase their alkalinity and therefore their carbon uptake.

Uncertainties and Barriers: Environmental and energy impacts from producing minerals needed for enhanced weathering. Competing or conflicting land use demands. Impacts on water systems that receive runoff from enhanced weathering areas. Impacts on water resources and water quality. Uncertainty about rates of dissolution of minerals, transport into ocean systems, and uptake of CO_2 from the ambient atmosphere.

FOOTNOTES

1 – Mace, M.J., Fyson, C.L., Schaeffer, M. Hare, W.L., *Governing large-scale carbon dioxide removal: are we ready?*, Carnegie Climate Geoengineering Governance Initiative (C2G2) at p. 32, (New York, US Nov. 2018); D. Sandalow et al., *Direct Air Capture of Carbon Dioxide: ICEF Roadmap 2018* at p. 20 (ICEF Dec. 2018); J. Minx *et al., Negative Emissions – Part 1: Research Landscape and Synthesis*, Envt'l Research Letters at pp. 5, 19-22 (May 2018), https:doi.org/10.1088/174-926/aabf9b .

2 – For example, the American Physical

Society released an influential early report that concluded a large DAC facility would cost $600 or more per metric ton of captured CO_2. The American Physical Society, APS Panel on Public Affairs, *Direct Air Capture of CO_2 with Chemicals: A Technology Assessment for the APS Panel on Public Affairs* (June 1, 2011). In a similar vein, the National Research Council of the National Academies National Research Council of the National Academies concluded that removing significant volumes of CO_2 with DAC could require up to 100,000,000 acres of land in the Southeast United States. This figure assumed, however, that the DAC units would rely solar on solar power sources that themselves require large amounts of surface land. Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration at 58, 62 (2015).

3 – K. Anderson and G. Peters, *The trouble with negative emissions*, 354 Science 182 (Oct. 14, 2016) ("Yet when it comes to the more stringent Paris obligations, studies suggest that it is impossible to reach 1.5˚ C with a 50 chance without significant negative emissions. Even for 2˚ C, very few scenarios have explored mitigation without negative emissions.")

4 – IPCC, 2018: Summary for Policymakers. *In: Global Warming of 1.5˚ C. An IPCC Special Report on the impacts of global warming of 1.5˚ C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty,* at p. 19 ("All pathways that limit global warming to 1.5˚ C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100-1000 Gt CO_2 over the 21 century.")

5 – M. Masnadi *et al., Global carbon intensity of crude oil production,* 61 Science 851, 853 (Aug. 31, 2018); C. McGlade and P. Ekins, *The geographical distribution of fossil fuels unused when limiting global warming to 2˚ C,* 517 Nature 187 (Jan. 8, 2015), doi:10.1038/nature14016.

6 – K. Gilblom, *JPMorgan Warns Oil Industry Faces Huge Costs to Reach Climate Goals,* Bloomberg News (Sept. 11, 2018), https://www.bloomberg.com/news/articles/2018-09-11/big-oil-seen-facing-monumental-costs-to-reach-climate-goals.

7 – NAS NET Research Agenda at 14.

8 – NAS NET Research Agenda at 133-34. The three companies with operating DAC facilities are Climeworks, Global Thermostat, and Carbon Engineering.

9 – Carbon Engineering adopted this strategy with its Squamish test plant. D. Keith, G. Holmes, D. St. Angel, and K. Heidel, *A Process for Capturing CO_2 from the Atmosphere*, Joule 2, 1-22 (Aug. 15, 2018), https://doi.org/10.1016/j.joule.2018.05.006.

10 – Id. at 9.

11 – For example, Carbon Engineering estimates that its technology, once fully scaled up, could produce fuels for less than $1 per liter, or roughly $3.79 per gallon. http://carbonengineering.com/about-a2f/ (under "Cost competitive" discussion). By comparison, consumer commercial gasoline in the United States sold for an average of $2.37 per gallon on December 18, 2018. https://gasprices.aaa.com/state-gas-price-averages/ (figures compiled by the American Automobile Association). Gasoline prices in California on that date totaled $3.40 per gallon because its laws and regulations impose more stringent emission and carbon emission standards for fuels. *Id.*

12 – K. Lackner et al, *The urgency of the development of CO_2 capture from ambient air,* 109 PNAS 13156, 13159 (Aug. 14, 2012), www.pnas.org/cgi/doi/10.1073/pnas.110876109 ; S. Schrage, *Technique doubles conversion of CO_2 to plastic component* (May 18, 2018), at https://phys.org/news/2018-05-technique-conversion-co2-plastic-component.html; S. Ahn *et al., Poly-Amide Modified Copper Foam Electrodes For Enhanced Electrochemical Reduction of Carbon Dioxide*, 8 ACS Catal. 4132-4142 (2018), doi: 10.1021/acscatal.7b04347.

13 – See, e.g., A. Otto, T. Grube, S. Schiebahn, and D. Stolte, *Closing the loop: Captured CO_2 as a feedstock in the chemical industry,* 8 Energy Environ. Sci. 3283, 3283-84 (2015), doi: 10.1039/c5ee02591e.

About UH Energy + CCME + EENR Center

UH ENERGY

UH Energy is an umbrella for efforts across the University of Houston to position the university as a strategic partner to the energy industry by producing trained workforce, strategic and technical leadership, research and development for needed innovations and new technologies.

That's why UH is THE Energy University.

CCME

The Center for Carbon Management in Energy works to identify and develop possible carbon management strategies applicable during the production, management, and distribution of energy resources and products. These carbon management strategies include, but are not limited to, carbon capture and utilization during energy production and distribution as well as negative emissions technologies.

EENR CENTER

The Environment, Energy & Natural Resources Center at the University of Houston Law Center links energy issues with impacts on environment and natural resources. Building on the academic excellence of the faculty in these areas and the complex and multi-faceted energy and environmental issues in Houston, the Center provides a forum for education and discussion of the most important issues of the day, such as climate change, air pollution, clean coal and renewable energy.

UNIVERSITY of HOUSTON
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APPENDIX C

UNIVERSITY of HOUSTON | UH ENERGY

Federal Pricing of Carbon

A Snapshot from February 2018

Authored by the Environment, Energy, and Natural Resources Center in collaboration with UH Energy

UH Energy White Paper Series: No. 02.2018

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Professor Victor B. Flatt returned to the University of Houston in 2017 as the Dwight Olds Chair in Law and the Faculty Director of the Environment, Energy, and Natural Resources (EENR) Center. He also holds an appointment as a Distinguished Scholar of Carbon Markets at the University of Houston's Global Energy Management Institute. He was previously the inaugural O'Quinn Chair in Environmental Law at UHLC from 2002-2009.

Professor Flatt is a recognized expert on environmental law, climate law, and energy law. His research focuses on environmental legislation and enforcement, with particular expertise in the Clean Air Act and NEPA. He is co-author of a popular environmental law casebook, and has authored more than 40 law review articles, which have appeared in journals such as the Notre Dame Law Review, Ecology Law Quarterly, Washington Law Review, Houston Law Review and the Carolina Law Review. Six of his articles have been recognized as finalists or winner of the best environmental law review article of the year, and one was recognized by Vanderbilt University Law School and the Environmental Law Institute as one of the three best environmental articles of 2010, leading to a seminar and panel on the article in a Congressional staff briefing.

Professor Flatt has served on the AALS sub-committees on Natural Resources and Environmental Law, and was chair of the AALS Teaching Methods Section. He has served on many other board and committees in his career including the national board of Lambda Legal, and the Law School Admission Council's Gay and Lesbian Interests section. He is currently on the Advisory Board of CE3, a member of the ABA's Section on Environment, Energy, and Natural Resources Law Congressional Liaison Committee, and a member scholar of the Center for Progressive Reform.

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EXECUTIVE SUMMARY

On February 21 and 22, 2018, the University of Houston's Environment, Energy, and Natural Resources (EENR) Center, the UH Energy Initiative, Duke University's Nicholas Institute for Environmental Policy Solutions, and the Duke University Energy Initiative hosted an invitation only event to review the literature surrounding the debate between pricing carbon with cap and trade or a direct tax, and discuss what we have learned about these pricing mechanisms and their future. As an innovation in such discussions, the organizers, with the assistance of the National Fiscal Association brought in experts in tax policy to interact with those who have studied the environmental, economic and political costs and benefits of cap and trade vs. direct carbon taxation.[1]

Discussions and presentations focused on how revenue-similar carbon cap and trade v. carbon tax allowed a better regulatory design to accomplish goals and/or were easier politically. The workshop allowed an in depth discussion by representatives from law, policy, tax, and climate to engage with the questions. While there was no definitive conclusion on which system is best for regulation and ease of adoption, the participants did make several observations important to the continuing policy debate. All agreed that the rhetoric surrounding these solutions has changed significantly since it was last visited in Congress, and that under the current political climate, carbon pricing was more likely to occur through an add-on to existing policy mechanisms rather than a completely new mechanism. This indicates that some form of taxation (though not necessarily economy-wide) might be the first federal carbon pricing statute.

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BACKGROUND

Although "cap and trade" has been declared "dead" in terms of U.S. climate policy, this method for controlling greenhouse gas emissions covers over half of all economic activity in Europe, and 80-85% in California, Quebec, and Ontario (all of which have linked cap and trade systems). The "cap" on greenhouse gas emissions is set by the government across an industry, and can be "traded" in a market for companies to buy and sell allowances and therefore set a market-driven price for carbon. According to the World Bank's 2017 carbon pricing report, over 67 jurisdictions around the world, representing half of all economic activity and a quarter of all carbon emissions, have a carbon pricing mechanism.[2] Over three quarters of these jurisdictions use cap and trade as the preferred carbon pricing mechanism.[3] China has released its plan for a carbon intensity cap and trade system to control greenhouse gas emissions in that country,[4] and cap and trade is used for this same purpose to varying degrees in Japan, New Zealand, and South Korea. Many of the other large greenhouse gas emitters that are party to the Paris Agreement (such as Brazil, Mexico, and Indonesia) have indicated that they will use cap and trade, tax and/or offset protocols to assist in meeting their greenhouse gas reduction targets.

Much like "cap and trade," carbon taxes have similarly been declared "dead," but in the United States, the recent enactment of the Tax Cuts and Jobs Act (TCJA) is estimated to add $1.5 trillion to the federal deficit.[5] Politically, the passage of the TCJA spurred some discussion of carbon pricing as an additional revenue source.[6] Carbon tax as a form of greenhouse gas control has been touted as the "most efficient" means of reducing greenhouse gases by noted economists around the world,[7] and has been used in British Columbia, and on January 9, 2018, was fast tracked for possible implementation in Washington State by Governor Jay Inslee. Though that attempt was unsuccessful, a discussion of the use of carbon taxes continues in Washington and Oregon.

In 2017, a senior group of Republicans who had leadership positions in previous presidential administrations proposed a multi-year tax on greenhouse gases for United States policy, tying it to reduction in other taxes and matching it to the expected growing costs of greenhouse gas impacts on the world.[8] This attempt has been cited and approved of by other conservative organizations.

When the United States was considering a comprehensive economy-wide greenhouse gas cap and trade program in 2008-09, there were sporadic discussions in legal and economics literature about the relative benefits of use of a carbon tax vs. the use of a cap and trade system. The time seemed right for a re-examination.

Additionally, a federal mandated carbon pricing mechanism will have a large business impact on fossil fuel energy companies. The major oil and gas companies have indicated a public support of a carbon tax but not a cap and trade system.[9]

Both a greenhouse gasses (GHG) cap and trade system and a GHG "tax" could either be used to raise additional funds to be spent by the government (an additional tax), or either could be made revenue neutral.

While this workshop examined a multiplicity of carbon pricing programs, one of the focuses was to compare revenue neutral carbon pricing programs. That is, if money coming into the system from consumers and taxpayers is offset (or given back to these persons in some form), which system would be politically, legally and practically best for the purpose of controlling greenhouse gas emissions in an efficient and transparent manner.
The participants were versed in legal and economic analyses of carbon pricing mechanisms. A list of related publications is included in Appendix A.

"Many of the other large greenhouse gas emitters that are party to the Paris Agreement (such as Brazil, Mexico, and Indonesia) have indicated that they will use cap and trade, tax and/or offset protocols to assist in meeting their greenhouse gas reduction targets."

WHAT HAS CHANGED SINCE THE LAST FEDERAL CARBON PRICING DEBATE:

Since the failure to pass the American Clean Energy and Security ("ACES") bill in 2010, there have been many changes in both international agreements concerning climate change and the political, economic, and legal discourse surrounding carbon pricing within the United States.

Internationally, the predominant legal agreements for reducing carbon have gone from top down to bottom up, with the latest, the Paris Accord, compiling various country emissions targets. The pricing of carbon continues to be favored internationally as a greenhouse gas emission control mechanism, and more countries, and their political subunits, have embraced carbon pricing mechanisms domestically. Carbon pricing mechanisms are one of the forms of international cooperation enshrined in Article 6 of the Paris agreement.[10] Most of these carbon pricing mechanisms have taken the form of cap and trade systems, with an eye towards linking systems internationally. There are also newer and more complete data about what problems exist with cap and trade and how to address those problems. For instance, some now argue that cap and trade systems may lead to initial caps larger than optimal to provide the appropriate price signal for finding emission reductions.[11] This seems to come from both an over-estimation of baseline emissions and an under-estimation of ways to make cost effective reductions. Many cap and trade programs now have a price floor to avoid a complete collapse in prices. Such a floor can effectively function as a minimum carbon tax.

Offsets in cap and trade systems, which have been controversial from the beginning have faced more restrictions in newer systems. For instance, California's cap and trade offset allowances have specific and strict protocols for both set-up and enforcement. While this could make offsets more expensive than strictly necessary (and thus a less efficient CO_2 reduction system), it has provided more trust in the offset systems. Alternatively, restrictions on and legal uncertainty of the Clean Development Mechanism certified emissions reduction (CER) credits utilized in the EU Emissions Trading System have effectively sunk the market for those instruments.

Domestically in the U.S., the most important changes since 2010 are the initiation of California's economy wide cap and trade system, as well as the abandonment of proposed regional systems in other states. The lack of functioning regional systems, such as the Midwestern Climate Initiative, the original multi-state multi-province Western Climate Initiative, and the proposed Florida cap and trade system have been attributed by many to the failure of a federal cap and trade system to come into existence. Many of the prior proposed regional and state systems were envisioned as steps to integration with a larger national market. With the failure to create a national market, many of these plans were abandoned. The Regional Greenhouse Gas Initiative continues to operate in the northeast, and some states may yet try to join or integrate with the California system. The functioning and price stability of the California system have gone a long way in establishing that a cap and trade system can work in an economy – wide setting, and that its presence does not necessarily create a drag on the economy generally.

Politically in the United States, climate change rhetoric continues to be polarized, but there also seems to be more of a bi-partisan understanding, at least in some quarters, that either a carbon tax or a cap and trade system can be set up to create similar pricing signals and can either be revenue neutral or designed to raise revenue. This more sophisticated understanding allows the comparison of carbon tax vs. cap and trade focus more on the areas of uncertainty (amount of reduction in tax, price in cap and trade) as well as potential differences in ease of administration. It is these potential differences that provided a discussion focus at

the workshop.

KEY DISCUSSION POINTS AND CONCLUSIONS:

Although there was not complete agreement as to which carbon pricing system would be the "best" from a political and administrative stand-point, there were some points of agreement or focus that came from the day long discussion:

1) The term "tax" is no longer as politically toxic as it used to be. The thinking from 2009-2010 that a carbon tax could never be implemented because of the name is probably not true. Or at least the notion that cap and trade would be more favorably viewed politically is not true.

2) The need for additional federal revenues or desire for more tax simplification and reform may at some point provide impetus for implementing some carbon pricing system.

3) Any federal carbon pricing system needs to be easily understandable and not too complex. Complexity creates concern about gaming systems. Some revenue neutral systems (such as tax and dividend) are very simple to understand, and complexity increases with the introduction of more and more policy choices (i.e. how should we spend government revenues or which taxes should be offset).

4) The implementation of a carbon pricing system is not likely to come from a direct policy push, i.e. stand-alone carbon pricing laws may be less likely than carbon pricing as an adjunct to other policy desires (such as tax reform).

5) Assuming that carbon pricing may not be a stand-alone law, it seems more likely and feasible that a "carbon tax" could be implemented as a part of tax reform and/or revenue enhancement. Moreover, the existing tax system (such as fuel taxes for highway infrastructure or wellhead taxes on energy) could be utilized to put higher taxes on carbon in some sectors of the economy without such policy even being designated as "pricing carbon." However, increases in energy taxes may bring up issues of competitive advantage in product manufacturing and whether or not that should or could be addressed with border adjustment policies.

6) Path dependency may favor a cap and trade system, particularly internationally. While a tax system and a cap and trade system could be integrated, international carbon pricing continues to be dominated by cap and trade and attendant offset systems.

7) Border tax adjustments based on differing carbon pricing policies may be on sounder legal footing with WTO rules if the carbon pricing is done through a direct tax as opposed to a cap and trade system.

8) While there was not a consensus on this point of view, some workshop participants argued that, compared to a tax, cap and trade systems create a private incentive for enforcement which mitigates rent-seeking by creating a constituency that would oppose system changes because of an impact on investment.

9) Taxes can be designed to limit rent seeking. This is best done by establishing a tax schedule in which the tax rises by a set amount over time, rather than is re-set each year administratively and thereby subject to continued political influence.

10) There was disagreement about whether administrative agencies should be able to have much discretion in altering these prices.

11) The conservative case for carbon pricing is strongly dependent on federal and possibly state pre-emption of using other laws to try and limit CO_2 emissions. This could be a major sticking point in passing a stand-alone federal law.

"Assuming that carbon pricing may not be a stand-alone law, it seems more likely and feasible that a "carbon tax" could be implemented as a part of tax reform and/or revenue enhancement."

FOOTNOTES

1 – We use the term cap and trade for greenhouse gas emissions trading systems because that is common usage. However, many of these emissions trading systems have set-offs or offsets, which are not specifically cap and trade as that is used in the Clean Air Act Emissions Trading System.

2 – World Bank GRP., et al., State and Trends of Carbon Pricing (2017), https://openknowledge.worldbank.org/bitstream/handle/10986/28510/wb_report_171027.pdf?sequence=7&isAllowed=y.

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9 – Tina Rosenberg, Guess Who's for a Carbon Tax Now, *New York Times* (April 11, 2017), https://www.nytimes.com/2017/04/11/opinion/guess-whos-for-a-carbon-tax-now.html.

10 – World Bank GRP., et al., supra note 1.

11 – Michael Wara, Instrument Choice, Carbon Emissions, and Information, 4 MICHI. J. ENVTL. & ADMIN. L. 261, 274 (2015); see also Lesley K. McAllister, The Overallocation Problem in Cap-and-Trade: Moving Toward Stringency, 43 COLUM. J. ENVTL. L. 395, 397 (2009).

APPENDIX A - RELEVANT READINGS

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Resolving the Inherent Uncertainty of Carbon Taxes: Introduction
Joseph E. Aldy, Marc Hafstead, Gilbert E. Metcalf, Brian C. Murray, William A. Pizer, Christina Reichert & Roberton C. Williams III

Increasing Emissions Certainty Under a Carbon Tax
Brian C. Murray, William A. Pizer, & Christina Reichert

Designing and Updating a U.S. Carbon Tax in an Uncertain World
Joseph E. Aldy

Adding Quantity Certainty to a Carbon Tax Through a Tax Adjustment Mechanism for Policy Pre-Commitment
Marc Hafstead, Gilbert E. Metcalf, & Roberton C. Williams III

To Negotiate a Carbon Tax: A Rough Map of Interactions, Trade-offs, and Risks
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Resources for the Future, Implementing a Carbon Tax
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About UH Energy + EENR Center

UH ENERGY

UH Energy is an umbrella for efforts across the University of Houston to position the university as a strategic partner to the energy industry by producing trained workforce, strategic and technical leadership, research and development for needed innovations and new technologies.

That's why UH is the Energy University.

EENR CENTER

The EENR Center at the University of Houston Law Center links energy issues with impacts on environment and natural resources. Building on the academic excellence of the faculty in these areas and the complex and multi-faceted energy and environmental issues in Houston, the Center provides a forum for education and discussion of the most important issues of the day, such as climate change, air pollution, clean coal and renewable energy.

UNIVERSITY of HOUSTON
LAW CENTER
Environment, Energy & Natural Resources Center

APPENDIX D

EDUCATION. INNOVATION. PARTNERSHIPS.

WE ARE **HOUSTON'S** ENERGY UNIVERSITY.

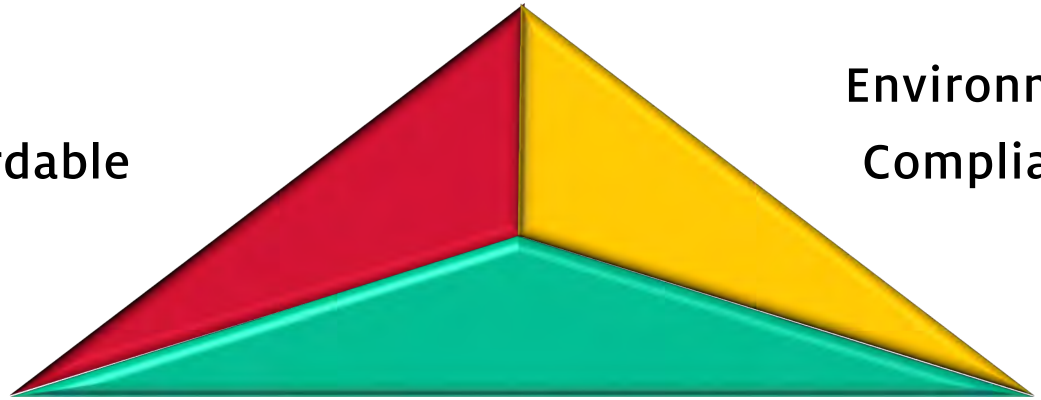
UNIVERSITY of **HOUSTON** | **UH ENERGY**

CENTER FOR CARBON MANAGEMENT IN ENERGY - CCME

MISSION: Establish a globally recognized Center for Carbon Management in Energy to identify the key challenges and solutions necessary to lead the lower carbon future for the energy industry and societal marketplace.

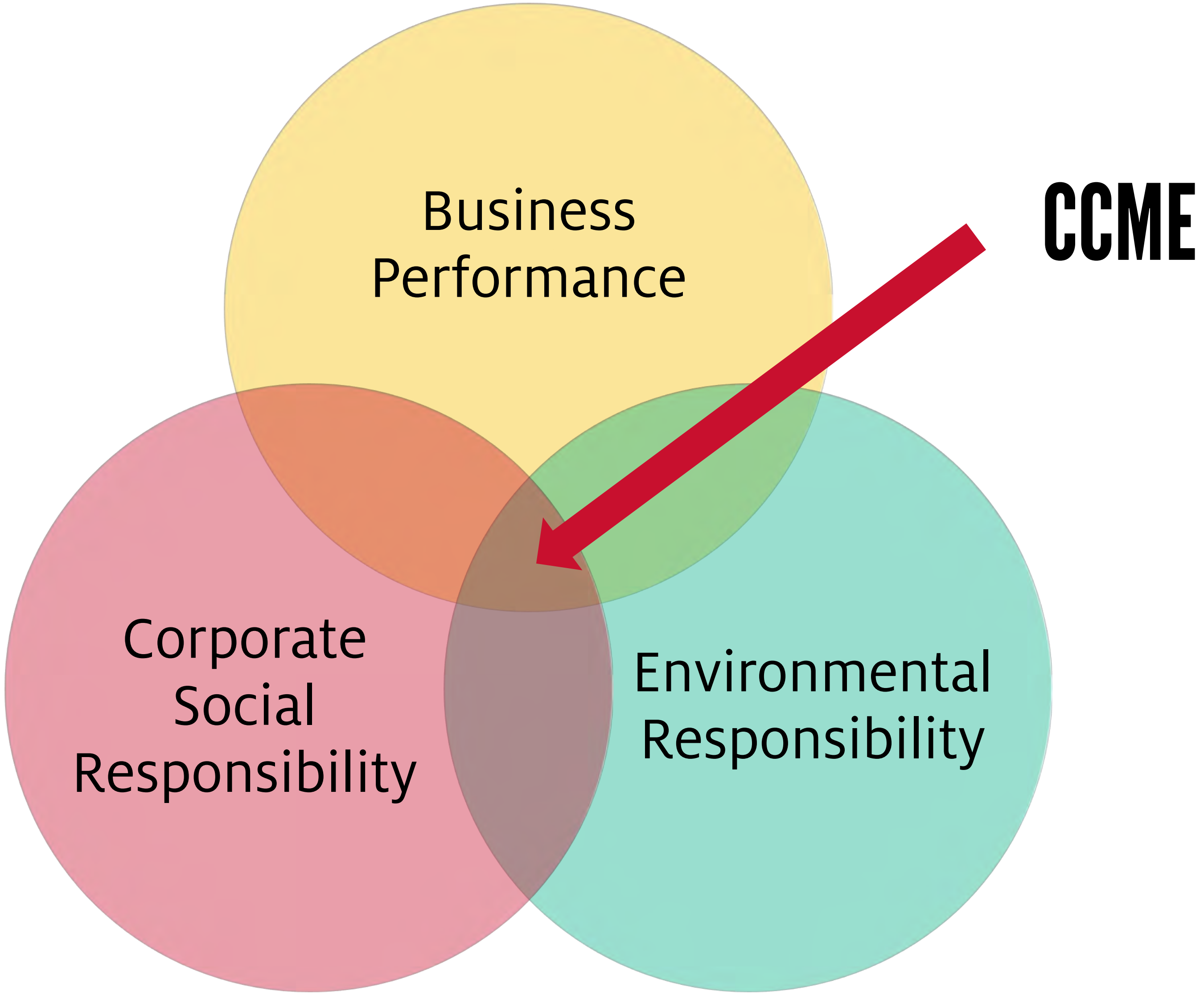
The UH CCME will be strategically driven by the challenges in oil and gas production, petrochemicals, and electric power sectors (including renewable energy platforms), as well as the entire energy value chain to consumer end use, to advance innovative and transformative solutions for a sustainable energy future.

ENERGY SUSTAINABILITY is the Foundation

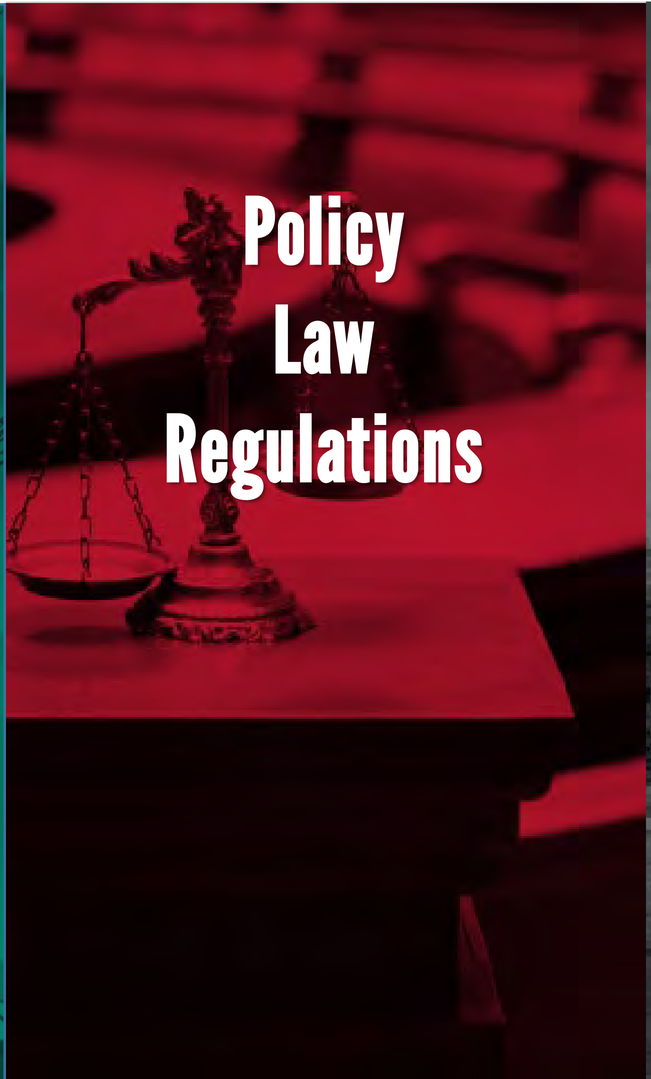


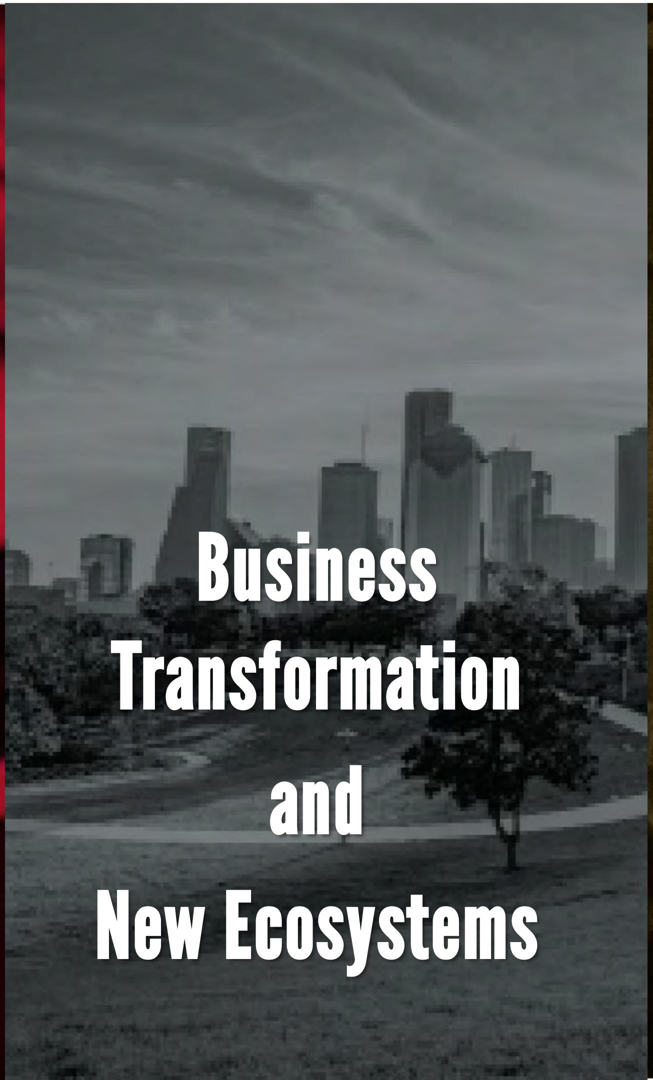
- Pursue all requirements in harmony – a balanced public view
- Global perspectives and Industry priorities - Developed and Developing worlds
- Embrace transformative approaches and policy to create the future
- New Energy ecosystems to transform science and technology development and investment in breakthrough materials, products, capabilities, and commerce

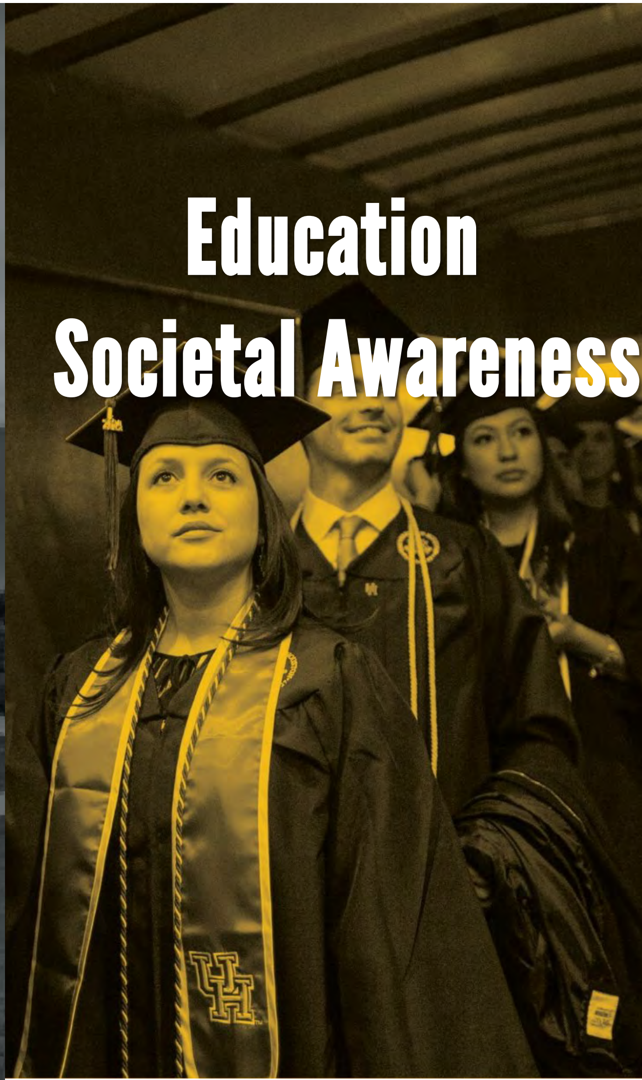
STRATEGIC FOCUS



KEY STRENGTHS AND CAPABILITIES FOR CCME







Technology & Innovation

- Key Markets: Oil and Gas; Petrochemicals; Electric Power
- Systems Approach to Each Market and Value Chain

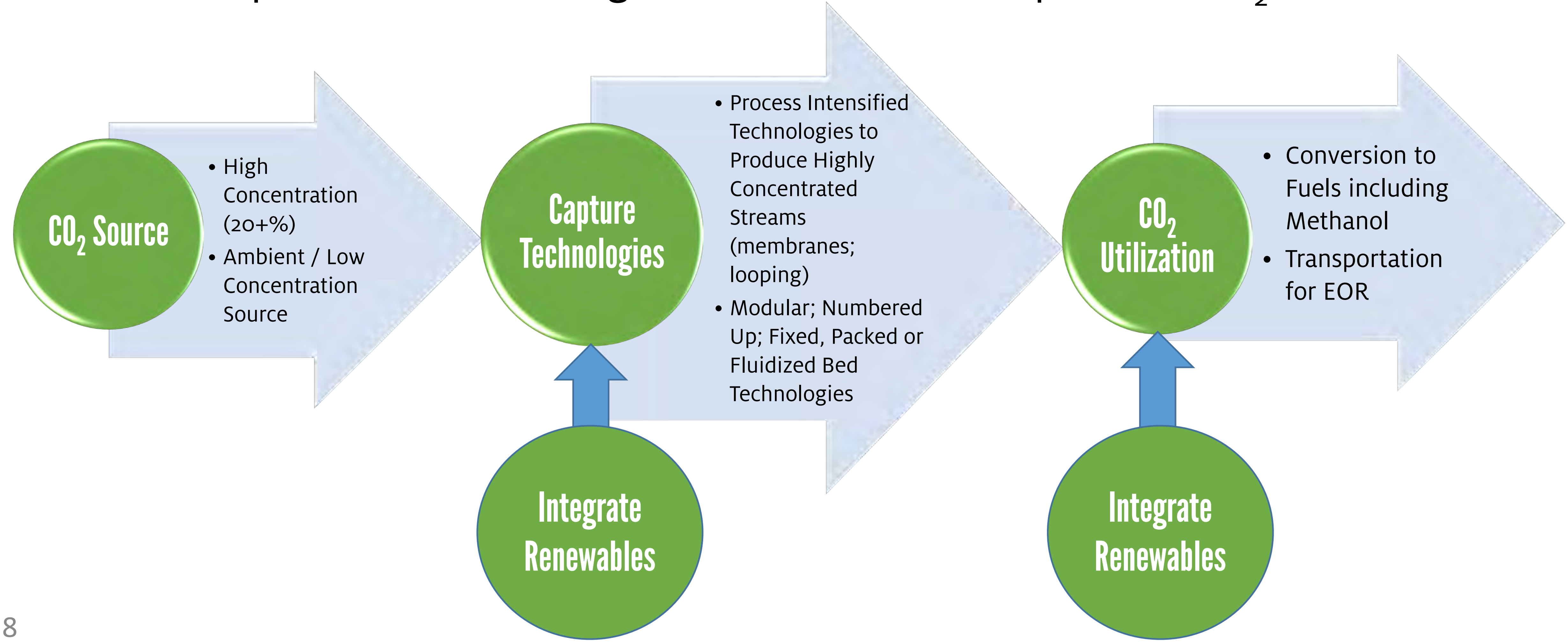
	Accretive Utilization	Emissions Reduction and Mitigation
CO_2	EOR and CCUS	CCUS and Integrated Processes
CH_4	Conversion	Monitoring and Mitigation
Hydrocarbons	Conversion	Process Intensification

Technology & Innovation

	CO_2 Value Chain			Methane and Hydrocarbons	
	Capture	Transportation	Utilization and Sequestration	Emissions: Monitoring and Mitigation	Conversion and Monetization
Power Generation Hydrocarbon Exploration & Production Petrochemical Refining Chemicals and Fertilizers	Novel Capture Technologies: Adsorption; Selective Membranes; Modular & Distributed; Integration with Renewables Re-engineering Processes: Integration; Intensification	Pipeline Technologies: Materials, Corrosion & Leak Testing Shipping of CO_2: Technologies, Economics & Policies Compressors & Power Systems	Conversion: Fuels Chemicals Plastics Enhanced Oil Recovery: Conventional ROZ Unconventional Offshore Water Use & Recycle Geological Sequestration: Seismic, Acoustic, Modeling & Policy	Monitoring: (i) Remote Monitoring using Drones (ii) Distributed Acoustic Sensing Mitigation: (i) Pipeline Modeling (ii) Renewable Integration for Pneumatic Valves	Distributed Catalysis and Power Generation Conversion: Fuels (methanol) Chemicals Polymers & Materials Monetization: Gas Injection EOR

Technology & Innovation: Distributed Carbon Capture & Utilization

- Development of Technologies for Distributed Capture of CO_2



Technology & Innovation: Geologic Carbon Storage

Saline Aquifer Storage

- Primary storage*
  - Bulk CO_2 injection
  - Pressure limited
  - Infill wells to increase injection rate
- Secondary storage*
  - Displace water
  - Desalinate produced water
  - Reinject concentrate
  - Sell, discharge, or store fresh water

Other CO_2 Storage Options

- CO_2 EOR in tight oil and ROZ*
- CO_2 enhanced coalbed methane production
- Offshore EOR+ and saline aquifer storage*

* Various aspects of research and technology development supported by laboratory and modeling capabilities and skillsets existing at UH

CO_2 Enhanced Oil Recovery (EOR+)*

EOR+ Scenario	Description	Incremental recovery %OOIP	Net Utilization tCO_2/bbl	Net Carbon Ratio
Conventional	Miscible WAG flood with vertical injector and producer wells in a "five spot" or similar pattern. Operational practices seek to minimise CO2 use.	**6.5**	**0.3**	**0.7**
Advanced	Miscible flooding following current best practices optimised for oil recovery. May also involve some "second-generation" approaches that boost utilisation and recovery.	**13**	**0.6**	**1.5**
Maximum Storage	Miscible flooding where injection is designed and operated with the explicit goal of increasing storage. Could include approaches in which water is removed from reservoir to increase available pore volume.	**13**	**0.9**	**2.2**

Godec et al. 2011

Up to 139 $GtCO_2$ storage potential starting at $70/bbl oil price <u>excluding capture cost</u>

Technology & Innovation: Enhanced Oil Recovery

UNIVERSITY of HOUSTON
ENERGY INDUSTRY PARTNERSHIPS

LOOKING TO RECOVER MORE OIL?

BUILD A PARTNERSHIP WITH THE UNIVERSITY OF HOUSTON

UH's Energy Industry Partnerships (EIP) team will:

- Partner with your asset team to optimize production and maximize value
- Develop integrated solutions by following a multidisciplinary team (MDT) approach
- Provide expertise for conventional and unconventional fields

Energy Industry Partnerships (EIP) team is leading the charge to help the University of Houston emerge as the leading energy university by bringing value to the energy industry using smart, innovative and integrated approaches to the recovery of oil and gas through research pertaining to CO2 – EOR conventional & unconventional Reservoirs, waterflood/IOR, and integrated reservoir management – conventional & unconventional Reservoirs.

CO2 & Gas EOR laboratory mechanistic studies, pilot design and field implementation

Unconventional field development

Reservoir management with a multidisciplinary approach

IOR – Waterflooding and infill drilling

Integrated reservoir characterization and simulation

Technology & Innovation: EOR & CCUS Experience

CCUS Project Experiences:

- Alaska
- Texas including Permian
- North Sea & Continental Europe

Ganesh Thakur
Professor, Petroleum Engineering

Dimitrios G. Hatzignatiou
Professor, Petroleum Engineering

Christine Ehlig-Economides
William C. Miller Endowed Chair Professor of Petroleum Engineering

C02 Storage

- Abundant oil fields and Post EOR
- Site Assessments & Phase I – VI of Site Development: Best Practices
- Post Injection Closure & Long Term Monitoring Development

Development of Technology Roadmap to meet "Broad Commercial Deployment of CCUS" as per NPC Study & Recommendations

Technology & Innovation: Gas Injection

Foam Miscible Ethane Driven Oil Recovery in Low Permeability / Harsh Environments

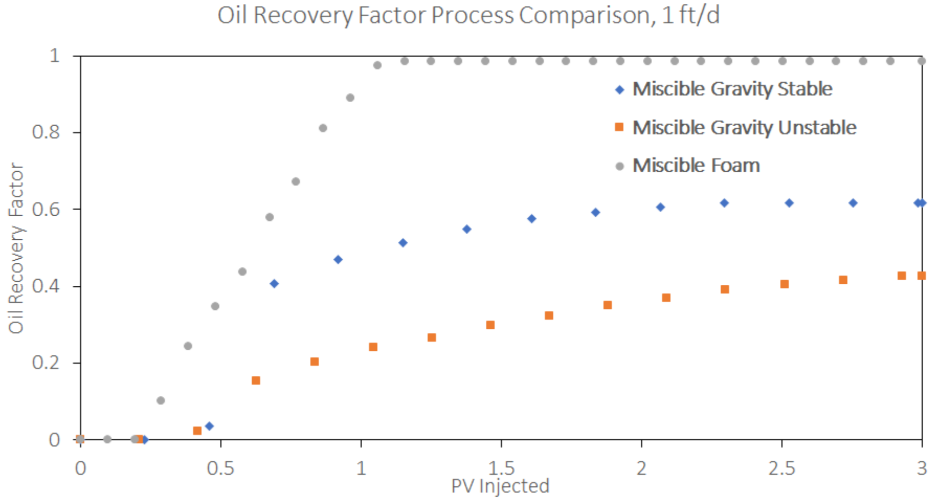
Key Takeaways from Lab Scale:

- Stable in Harsh Environments
- Gravity stable displacement delays gas breakthrough; higher recoveries
- Type I Low IFT miscible gas foams effective in a gravity unstable environment

Injectant	recovery @ 1 PV, %	recovery @ 3 PV, %
CO_2	80	95
100% ethane	82	97
100% methane	40	55
85% methane, 15% ethane	53	74
75% methane, 25% ethane	60	87
65% methane, 35% ethane	76	96

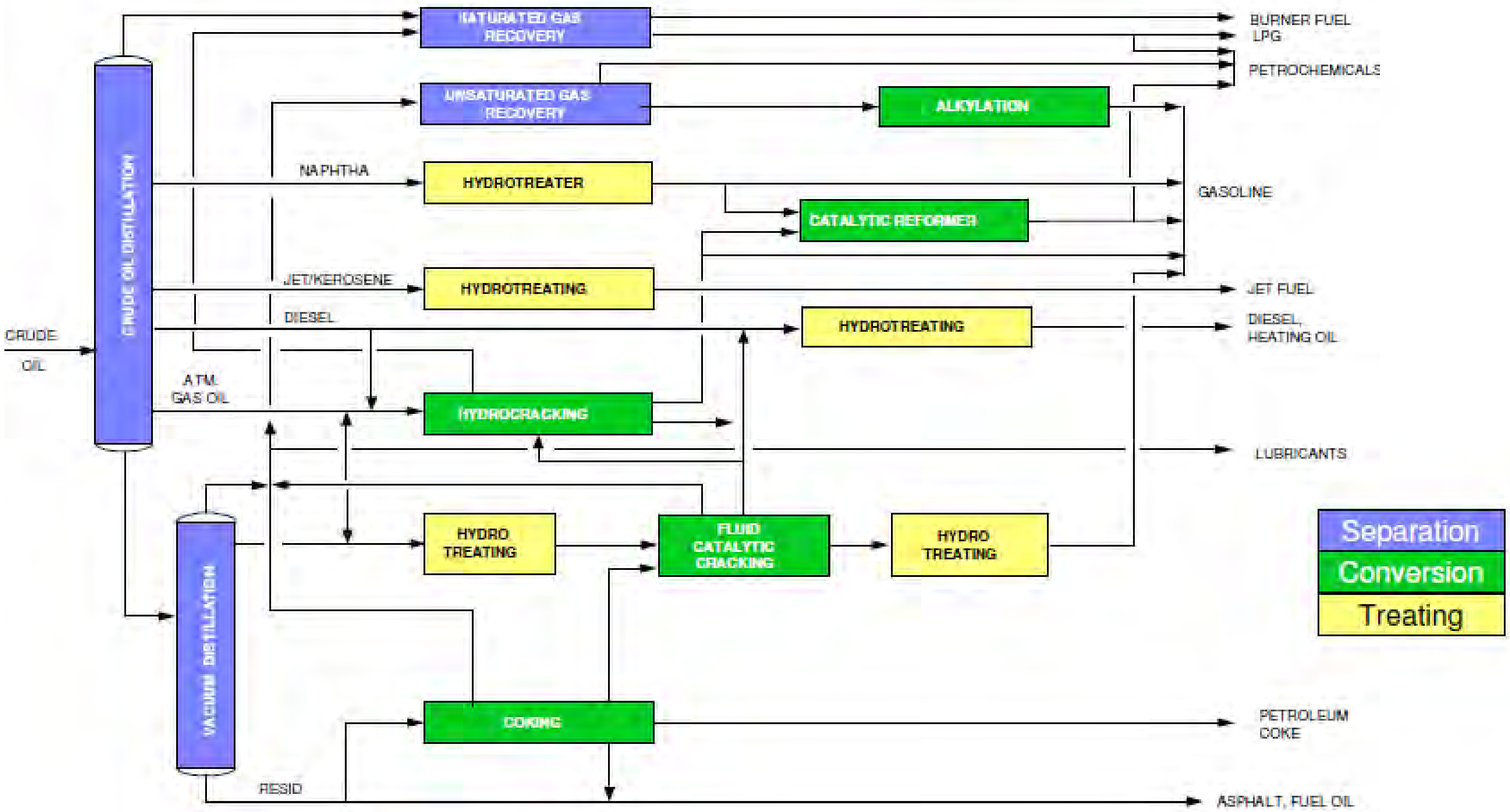
Next Steps:

- Displacement tests to characterize drive mechanisms
- Immiscible ethane foam process characterization
- Role of ethane vs. CO_2, N_2, and CH_4 in foam stability in porous media
- P_b depression in tight rock



UNIVERSITY of HOUSTON | UH ENERGY

Optimization & Reconfiguring: Refineries



Opportunities:

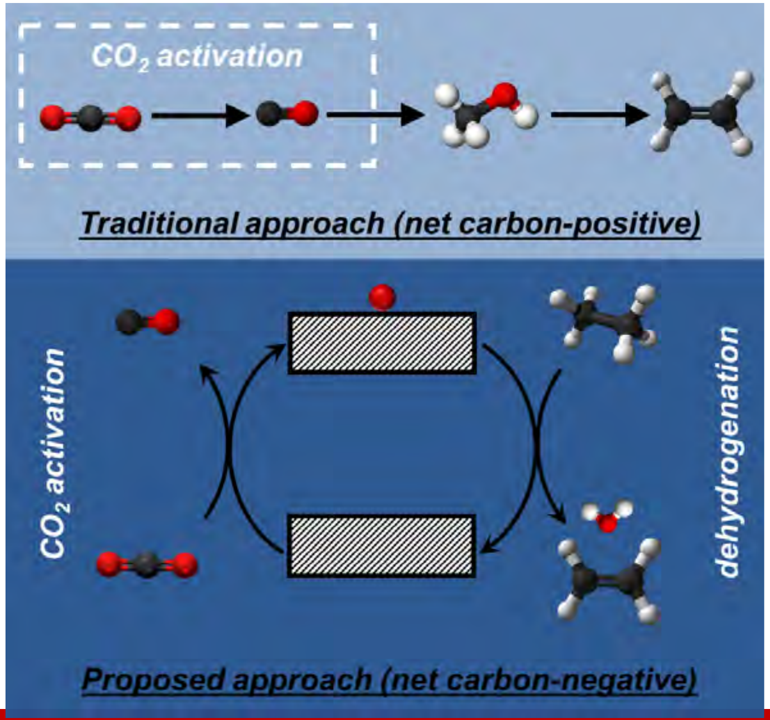
a. Energy Efficiency & Integration
b. Oxy-combustion for heat with CO_2 Capture
c. CO_2 to fuels
d. CO_2 to chemicals

Specific Cases:

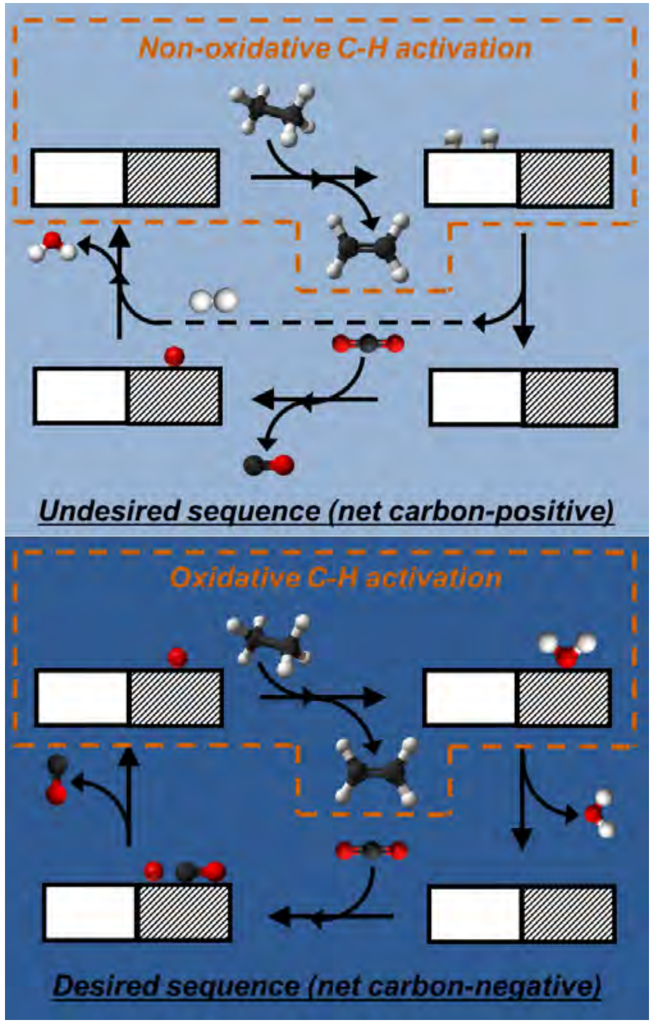
i. Furnaces and FCC Using O_2
ii. Electricity enabled air separation
iii. Electrochemical conversion of CO_2 to chemicals or fuels
iv. H_2 from renewables
v. Process Modeling
vi. Design & Simulations

Technology & Innovation: CO_2 a Soft Oxidant for Chemical Industry

CO_2 as a source of carbon and active oxygen

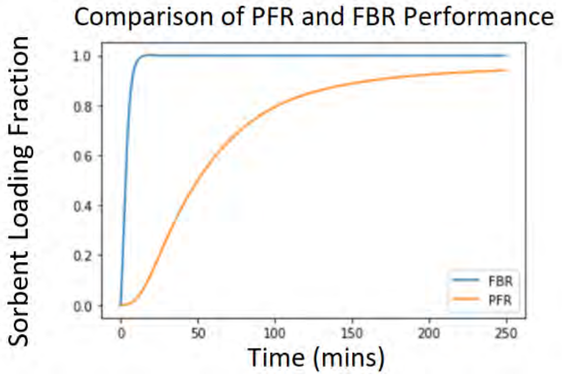


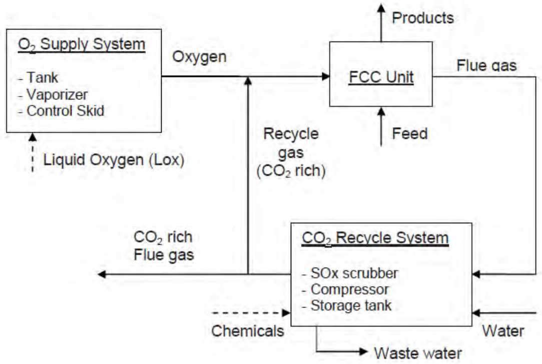
Can CO_2 be leveraged as a source of oxygen on catalyst surfaces to enable step-changes in process performance across the chemical industry?



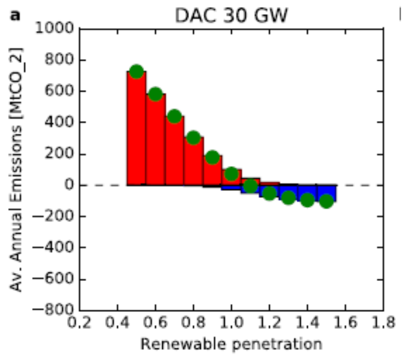
Technology & Innovation:
Carbon Capture & Utilization: Process Intensification

Goal: Develop process intensification and potentially modular routes for improved energy efficient carbon capture and utilization





Parameter	Reference	Study	Units
Capacity (BPD)	60,000	145,0000	BPD
Capacity Factor	-	0.6	
Cost Index	203	200	
CO_2 Produced	510	1,600	MTPY
CO_2 to Capture Plant (95%)	484.5	1,520	MTPY
CO_2 Capture Efficiency	90%	90%	
CO_2 Captured	436	1,370	MTPY
Capture Plant Capital Cost	174.4	291.75	$ MM
Capture Plant O&M Costs	18.2	30.5	$ MM/yr
Pipeline Capital Cost	-	167.3	$ MM
Pipeline O&M Costs	-	8.4	$ MM/yr
Storage Costs	2.94	4.92	$/tonne
Tax Rate	-	34%	
Depreciation Schedule	-	Straight Line	
CO_2 Avoided Cost	94	109	$/tonne



Key results:

- Evaluation of solid adsorbents for direct air capture of CO_2 including different reactor configurations. LCA's and techno economic evaluation along with process intensification underway.
- Developing modular intensified carbon capture systems paired with renewable power generation. Engineering analysis and field scale demonstration of various technologies ongoing
- Evaluation and optimization of processes and dual shipment model to integrate LNG and LCO_2 value chains.

Frontiers in Energy Research 7, 12 (2019)

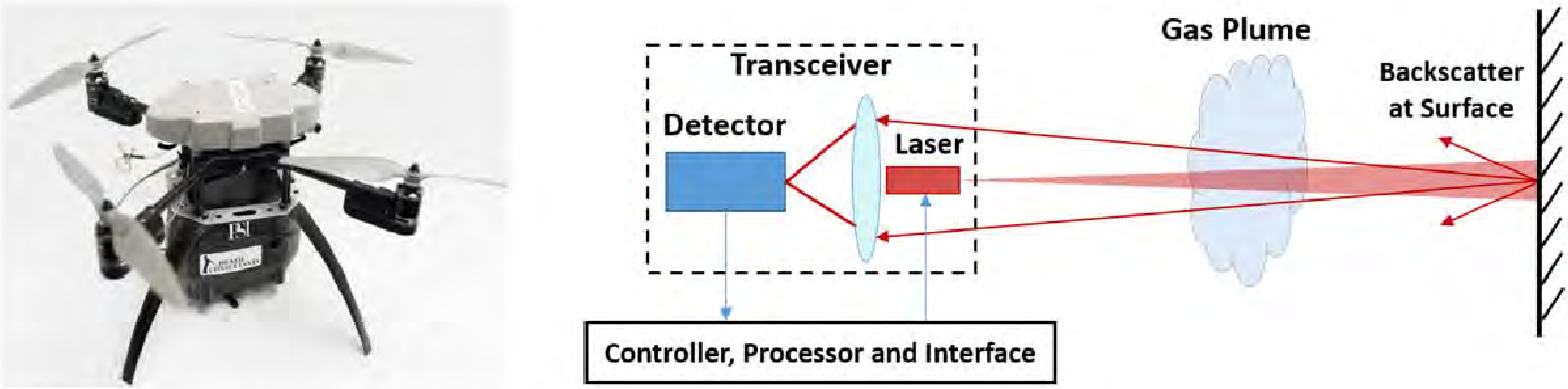
A UAV Drone System to Locate and Quantify Fugitive Methane Emissions

UNIVERSITY of HOUSTON
EARTH AND ATMOSPHERIC SCIENCES

Dr. Robert Talbot, University of Houston

Dr. Mickey Frisch, Physical Sciences, Inc.

PSI Physical Sciences Inc.

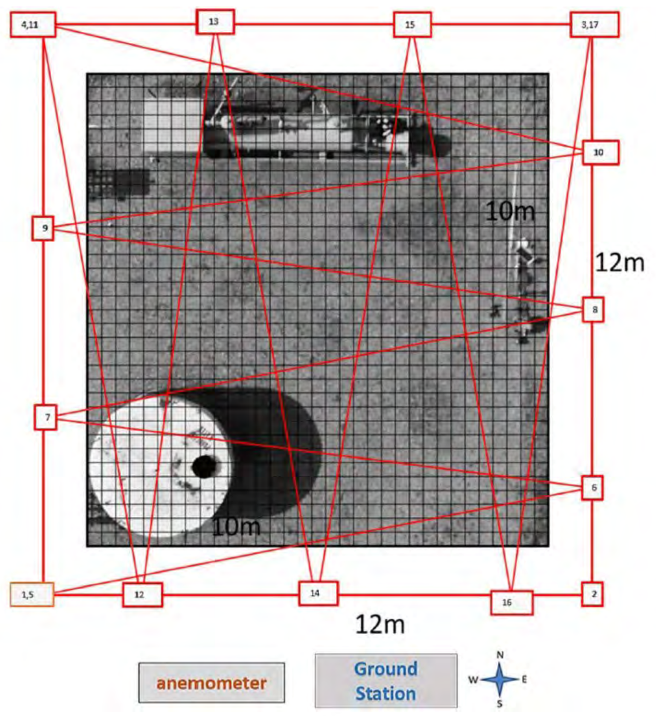


(a) (b)

Figure 1. (**a**) The images of the RMLD-UAV; (**b**) diagram of the basic premise of RMLD operation.

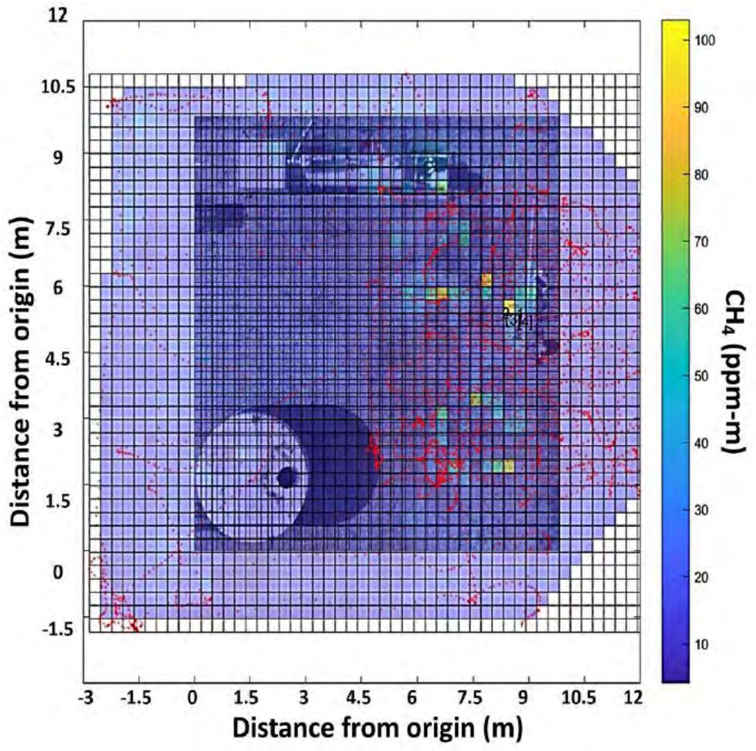
Three-Step Process to Locate and Quantify Leaks

Raster Scan of Area



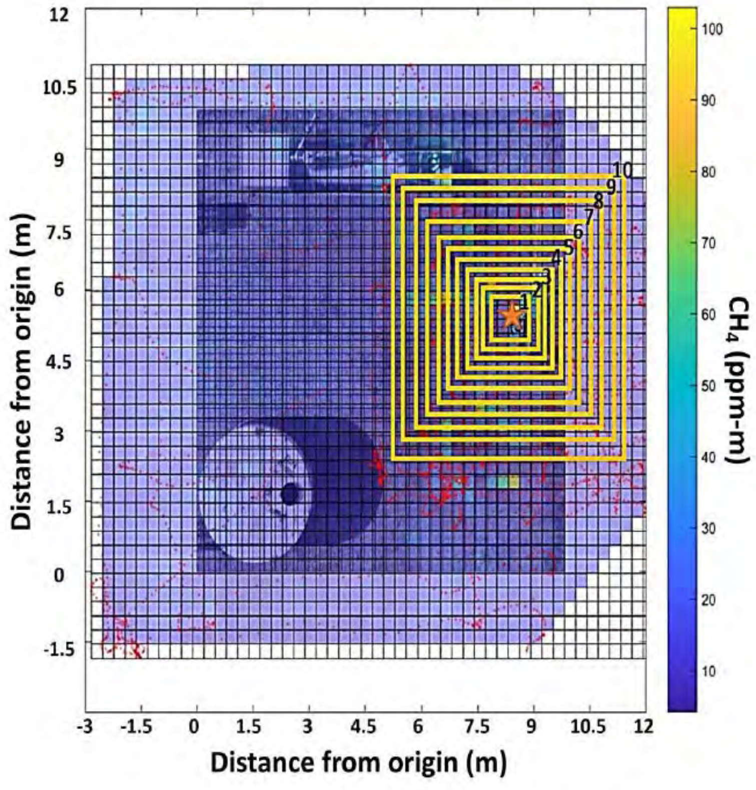
(a)

Interpolated Map of Measured Methane Mixing Ratios



(b)

Quantification Algorithm to Quantify Leak



(c)

UNIVERSITY of HOUSTON | UH ENERGY

Technology & Innovation

- Data Sciences & Computational Analysis
- Artificial Intelligence
- Robotics – Linkage to Subsea Systems Institute
- Process and Materials Optimization via Computational Analysis

POLICY, LAW & REGULATIONS

Regulatory & Public Policy:

Compliance and Assurance

Market Innovation

- Existing (example: 45Q Tax Credits)
- New: Low carbon products and services
- Incentivizing Negative Emissions Technologies
- Structure: Current and necessary frameworks

Expanded Policy & Research for Advocacy

- O&M
- Financial Investment
- Business Models
- Liability and Ownership
- Carbon Tax
- Cap and Trade
- International Trading and Investment
- International Clean Development Mechanisms

KEY CCME PROGRAMS

Science, Technology, Innovation & Policy - 2

- Systems Focus:
  - Power Generation and Integrating Carbon Capture
  - Zero Emissions Refineries
  - Process Intensification for Chemicals and Fertilizer Production
  - Integrated Flaring Mitigation + Renewables + EOR