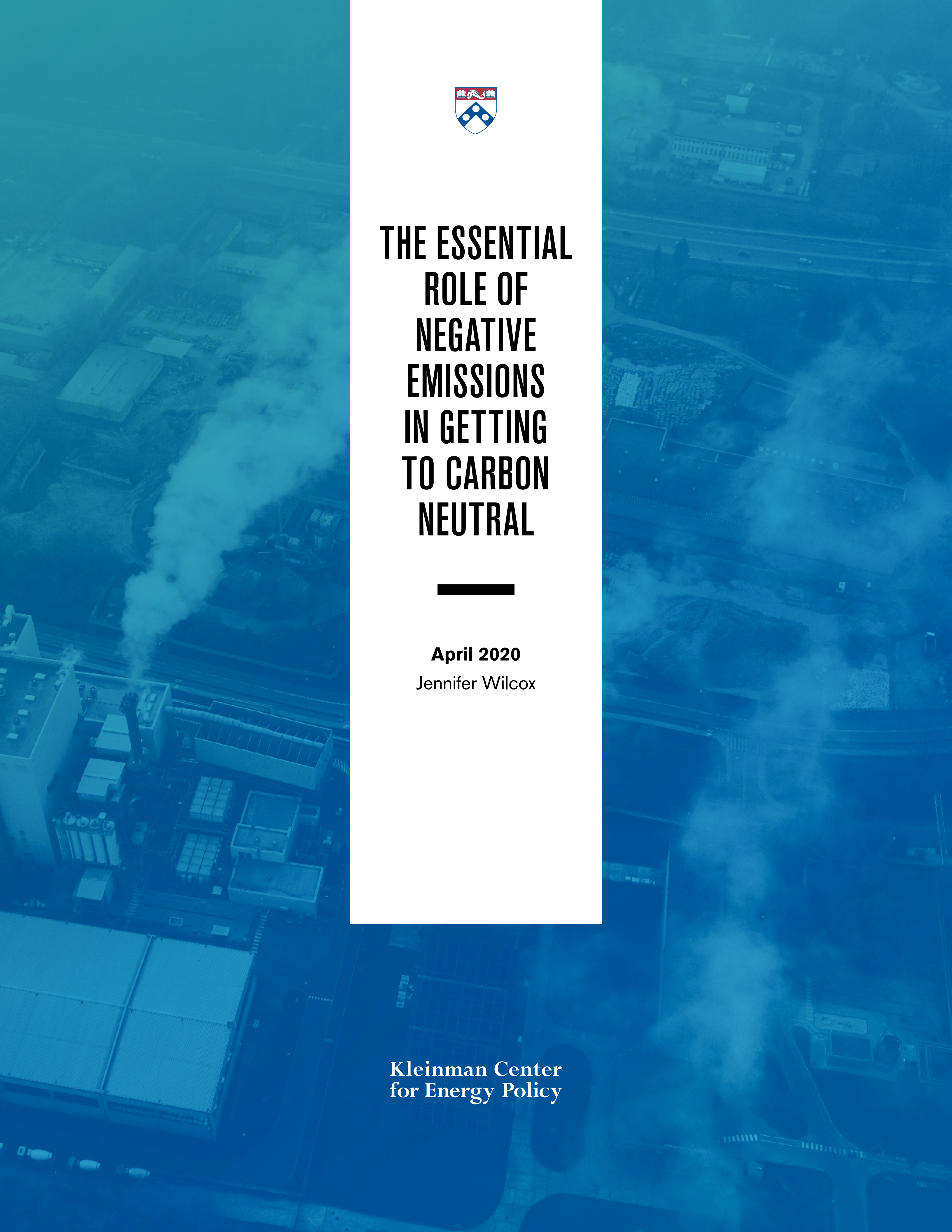

THE ESSENTIAL ROLE OF NEGATIVE EMISSIONS IN GETTING TO CARBON NEUTRAL

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To prevent global warming beyond the two-degree Celsius target set out in the Paris Climate Agreement will not only require deep decarbonization of our energy use, but also negative emissions, or the direct removal of CO_2 from the atmosphere. A 2019 report released by the National Academy of Sciences, Engineering, and Medicine (NASEM) concluded that 10 billion tonnes of CO_2 ($GtCO_2$) removal from air per year globally up to mid-century, in addition to 20 $GtCO_2$/yr from 2050 to 2100 will be required to meet climate goals (2019). To provide context, 10 $GtCO_2$ is roughly double the U.S. annual emissions today and a quarter of global annual CO_2 emissions. These negative emissions are in addition to deep decarbonization efforts that aim to avoid emissions in the first place.

WHY ARE NEGATIVE EMISSIONS ESSENTIAL TO MEETING CLIMATE GOALS?

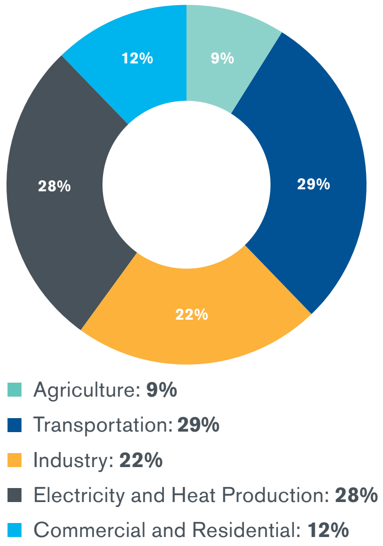
Anthropogenic emissions are dominated by fossil fuel burning, agriculture, and land use changes as demonstrated in Figure 1 (Pachauri et al. 2014). Each year, the ocean and terrestrial biosphere remove roughly half of these emissions that would otherwise increase atmospheric CO_2 levels.

The oceans, however, are experiencing first-hand the rising concentration of CO_2 in the atmosphere with increased acidification. Preserving ocean ecosystems therefore is one of the benefits that results from direct atmospheric removal of CO_2. Avoiding emissions will lead to CO_2 concentrations in the air to plateau at best. Only direct CO_2 removal from the atmospheric stock will lead to a decrease in atmospheric CO_2 concentrations.

However, to effectively reduce today's CO_2 concentrations, we must reduce emissions to at least half of what they are today. In other words, roughly 20 Gt CO_2/yr must be avoided for negative emissions to begin to have an impact (assuming the natural sinks will continue to remove the other half). From Figure 1, halving our emissions would mean significant changes in agricultural practice and land use changes, in addition to a significant decrease in our dependence on fossil fuels to meet our energy needs.

An additional benefit of negative emissions is the offset of emissions that are hard to avoid with current technologies, such as transportation and the industrial sector (i.e., iron and steel production, cement manufacturing, etc.).

FIGURE 1: DISTRIBUTION OF GLOBAL CO_2 EMISSIONS, WITH AGRICULTURE, ELECTRICITY AND HEAT REPRESENTING NEARLY HALF



Source: Pachauri et al. 2014

It is important to note that climate change impacts, such as increased warming, increased severity in storms, and increased regional aridity, have the potential to decrease the natural fluxes of the ocean and terrestrial biosphere. Understanding the interplay between the effects of climate change and the impacts of negative emissions on natural sinks will be important, since we rely on these natural sinks but want to limit the detrimental effects of increased ocean uptake that lead to its acidification.

WHAT ARE NEGATIVE EMISSIONS?

Broadly speaking, a negative emissions technology is one that removes CO_2 from the atmosphere on a timescale that has a positive impact on climate. The removal of CO_2 from air may take place through biology, minerals, or chemicals. The ocean and terrestrial biosphere are *naturally* doing this already, but the broader field of negative emissions technologies consists of accelerating these natural processes.

This can be done biologically by improving our land management, increasing forest and soil uptake of carbon, and converting biomass to a combustion feedstock for energy production. In this last case, however, the combustion-generated CO_2 must be captured and reliably stored in the Earth to prevent its re-release into the atmosphere. Enhanced mineral uptake takes place through the mineralization of CO_2 with alkalinity (i.e., calcium and magnesium) available in the Earth's crust. Finally, chemicals may be used for the selective reaction with CO_2 in air. This process is energy intensive, since the chemical feedstock needs to be regenerated for multiple capture cycle—and all that CO_2 must then be reliably stored for this approach to result in negative emissions.

ARE WE APPLYING NEGATIVE EMISSIONS TECHNOLOGIES TODAY?

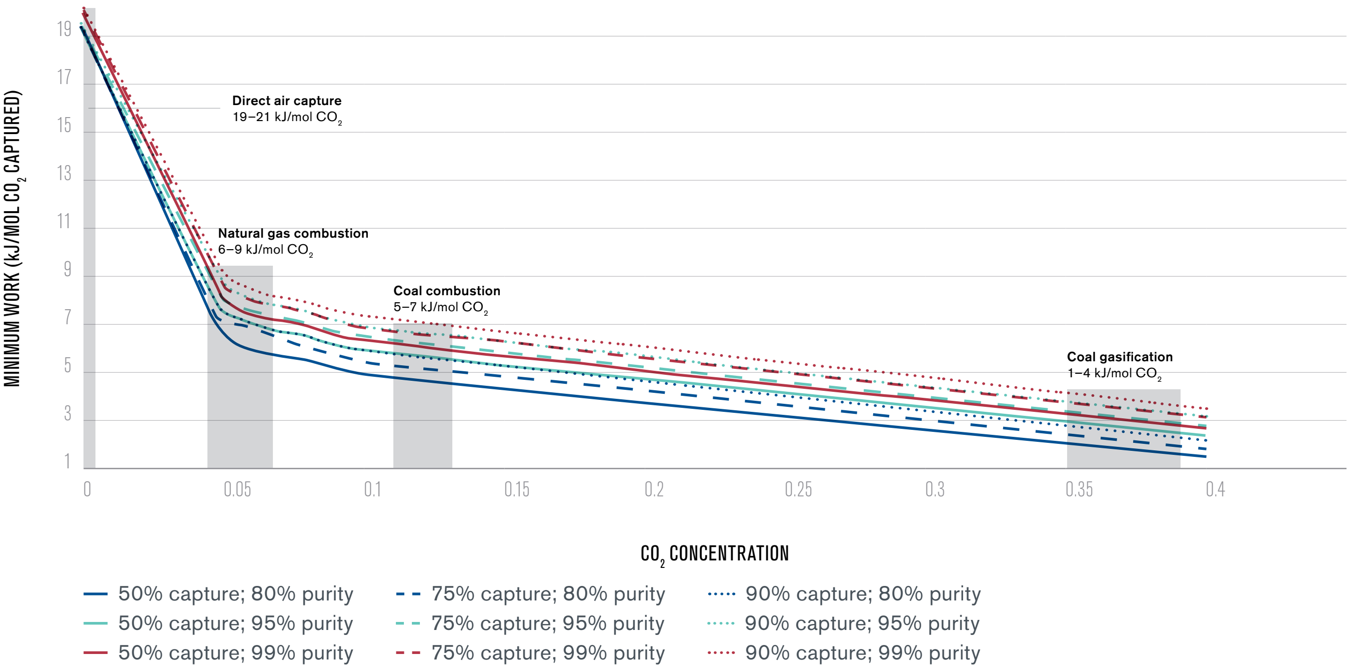
There are a number of negative emissions options that were outlined in a NASEM report and are available today for less than $100/tCO_2$, cumulatively estimated to achieve roughly 10 $GtCO_2$ removal globally per year (2019). These include planting trees, managing forests, and enhancing soil carbon storage and biomass energy with carbon capture and reliable storage. Although these approaches appear cost-effective, they are not always easily implemented, may have uncertain timescales of storage, and in some cases, may directly compete with food production.

The NASEM report indicated that negative emissions approaches such as direct air capture (DAC) and CO_2 mineralization will likely play a more significant role in terms of removal potential in the second half of the century, as these approaches advance with their costs made transparent through deployment.

Today, there are three global companies leading the field of direct air capture and operating demonstration-scale plants. Climeworks has 14 plants operating globally, collectively removing several thousand tonnes of CO_2 each year (Climeworks 2017; Gertner 2019). Carbon Engineering (Keith et al. 2018) has a demonstration plant in Canada with plans to build a plant in Texas designed to remove 1 million tonnes of CO_2 from air each year, and Global Thermostat (Brady 2018; Faulkner 2019) is finalizing a demonstration plant in the U.S.

A number of partnerships have developed that assist in subsidizing the capital expense of building DAC facilities. More specifically, partnerships have formed between 1) Coca-Cola Company subsidiary Valser and Climeworks (Coca-Cola HBC 2018), 2) Global Thermostat and ExxonMobil (ExxonMobil 2019), and 3) Carbon Engineering and Oxy Low Carbon Ventures (Carbon Engineering 2019), a subsidiary of Occidental Petroleum. Other recent collaborations include Climeworks partnerships with Audi (Audi MediaCenter 2015) and Rotterdam and The Hague airports (Climeworks 2019) to synthesize fuels from atmospheric CO_2.

FIGURE 2: THE RELATIONSHIP BETWEEN CO_2 INLET AND CONCENTRATION AND PERCENT CAPTURE TO MINIMUM WORK OF SEPARATION



Source: Wilcox 2012

Although these collaborations help in deploying DAC, many of these partnerships with DAC approaches lead to net emissions of CO_2 back into the atmosphere, diminishing their original goal of net removal. For instance, if the CO_2 captured from air is used to make a fuel and that fuel is subsequently oxidized, then it will be re-emitted back into the atmosphere. The same is true for partnerships with the food and beverage industry. These approaches may not result in the net removal of CO_2 from air today, but they do help in subsidizing the initial capital investment of the DAC facility. Further deployment on the scale of a thousand to a million times that of today and further, coupled to reliable storage of the CO_2 will be required to have a positive impact on climate.

WHY IS DIRECT AIR CAPTURE EXPENSIVE AND CAN WE EXPECT REDUCTIONS?

One can use the combined first and second laws of thermodynamics to estimate the minimum work of separating CO_2 from a given gas mixture, whether it be from air or the exhaust stream of a power plant. As demonstrated in Figure 2 (Wilcox 2012), the minimum work of separation increases with increasing dilution of CO_2. In particular, the minimum work of separating CO_2 from air (through DAC) is three times greater than separating it from the exhaust stream of a coal-fired power plant.

To achieve maximum removal of CO_2 from air, the energy resource used to power DAC should have very low- to zero-carbon emissions. Alternatively, one could couple DAC to natural gas. However, even if retrofitted with carbon capture, upstream methane emissions associated with natural gas processing may adversely impact the amount of CO_2 net removed from air.

What is the true cost of DAC deployment today? The estimates in the literature range broadly with the majority lacking significant deployment. However, Climeworks has demonstrated that on a commercial scale, the cost of DAC today is roughly \$600/tCO_2 with a vision to decreasing these costs down to ~\$200–300/tCO_2 within the next five years (Gertner 2019; Evans 2017).

RAMPING UP DIRECT AIR CAPTURE

It is important to recognize that today's demonstrated costs of DAC are not a limiting factor for its deployment. Rather, the lack of policy that puts a price on the permanent removal of CO_2 is limiting progress in both point-source capture of CO_2 and DAC. The storage of gigatons of CO_2 per year in the subsurface will be an essential element to meeting our climate goals.

In the United States, DAC qualifies for two policy incentives in place today. The federal tax credit 45Q provides up to $43/t$CO_2$ for utilization such as CO_2-EOR and up to $62/t$CO_2$ for geologic storage. In addition, California has a low-carbon fuel standard (LCFS) that places a cap on the maximum carbon intensity (CI) of transportation fuels sold in California and grants credits for fuels below the CI requirement. Today, the credit is being traded up to $200/t$CO_2$. An entity that operates DAC coupled to geologic storage anywhere in the world may qualify. Geologic storage of CO_2 includes enhanced oil recovery (EOR), enhanced gas recovery (EGR), and dedicated geologic storage projects (CARB 2018).

Today, CO_2-EOR is the largest CO_2 market in the U.S. Although most CO_2 for EOR today is sourced naturally, it is anticipated that with regulations in place such as California's LCFS and federal tax credit 45Q, there will be greater incentive to use CO_2 from exhaust or industrial streams (45Q applies) and even CO_2 from air (both incentives apply). Recent work of Psarras et al. (n.d.) has estimated the availability of 40 MtCO_2 from natural gas power plants within 20 miles of existing CO_2 pipelines and with delivered costs (including capture based on the work of Rubin et al. (2015), compression and transport) as low as $40/t$CO_2$ and $56/t$CO_2$ for geologic storage and EOR, respectively.

In addition, recent work of Pilorgé et al. (n.d.) carried out a siting and cost study on the retrofit of carbon capture on a number of various industrial facilities including refining, iron production, and cement manufacturing. From their analysis, they found that there was the potential of avoiding up to 40 MtCO_2 within 100 miles of existing CO_2 pipelines, and additionally 70 MtCO_2 costing less than $40/t$CO_2$ when applying 45Q for qualifying streams.

The industries representative of the lower costs are primarily comprised of cement manufacturing, hydrogen production, and bioethanol production. In addition, since these scales of capture are on the order of thousands of tonnes per year, rather than millions of tonnes (power plants), trucking tends to be more economic [than pipeline], which may enhance the rate of deployment. Increasing 45Q beyond $62/t$CO_2$ reliably stored will further bridge the economic gap to advancing geologic storage projects, which will be an essential step to both deep decarbonization and negative emissions approaches.

HOW IS THE RECOVERY OF OIL ENHANCED USING CO2?

Supercritical CO_2 (> 73.8 bar and > 32.1 °C) is considered to be a "green" solvent as it is relatively inert, non-flammable, and non-toxic. Common applications of the use of supercritical CO_2 as a solvent include coffee and tea decaffeination, nicotine extraction, and hops extraction. CO_2-EOR is considered a tertiary method of recovering oil while water flooding is a secondary method. On average only 30 to 50 percent of the oil is recovered after secondary recovery with 50 to 70 percent remaining in the reservoir. Globally, an estimated 40 MtCO_2 are reliably stored in the Earth each year, with over 90 percent of these projects associated with CO_2-EOR. Although much of the CO_2-EOR activity takes place in the U.S., other countries include Canada, Brazil, Turkey, China, Norway, Saudi Arabia, UAE, and Malaysia (Verma 2015; Global CCS Institute 2019; Sweatman et al. 2011; IEA 2015; Kuuskraa and Wallace 2014).

CAN OIL RECOVERED FROM CO2-EOR HAVE A NEUTRAL OR NEGATIVE CARBON FOOTPRINT?

When oil and gas have been depleted from a reservoir, there becomes pore space void of oil and gas that may be available for CO_2 to reside.

Today, when carrying out a CO_2-EOR project, all the CO_2 used is ultimately stored in the Earth, but this amount is minimized since this represents a significant cost to operators, i.e., up to \$40/tCO_2 depending on the price of oil or access to the naturally sourced CO_2 in the Earth (NETL 2010; Kuusraa et al. 2011; Martin et al. 2011; Middleton 2013). Just as oil and gas have been stored in the Earth for millions of years, there are natural storage reservoirs of CO_2, primarily located in the Rocky Mountains and the Colorado Plateau, with smaller extents located in the Permian Basin and Gulf Coast regions (Nichols 2014). In addition, the mechanisms by which CO_2 has remained trapped in the Earth are the same as those that trap oil and gas, some of these trapping mechanisms include faults and low-permeability cap rock (e.g., clay) (NASEM 2019; Kelemen et al. 2019).

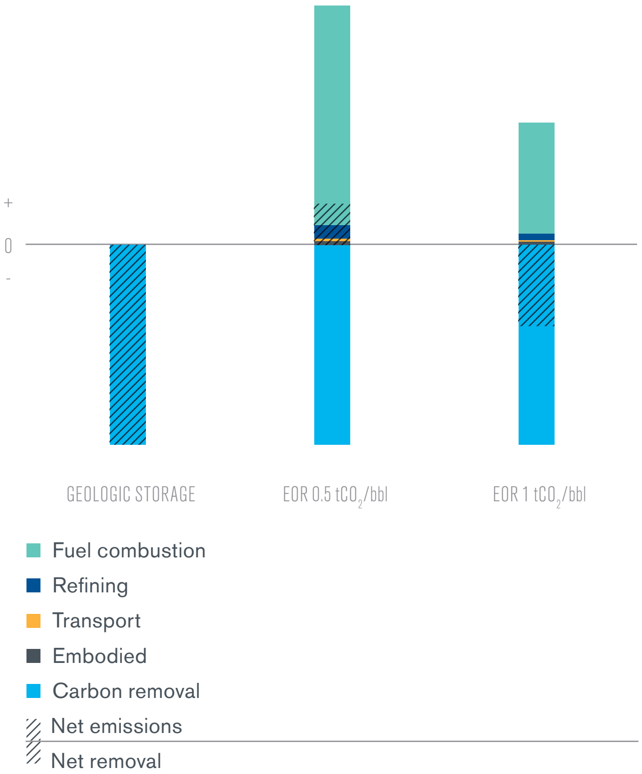
Many of the formations that are suitable for CO_2-EOR are stratified formations in the Earth with some of the pores containing residual oil and others potentially containing only saltwater. Therefore, some of these formations have the potential to serve dual purposes: CO_2 storage via EOR and dedicated storage, in which no oil is recovered.

To understand the impact of decisions downstream from atmospheric CO_2 removal, life cycle emission data (Núñez-López 2019; Brandt 2015; Argonne National Laboratory 2019) can be used to compare three scenarios as shown in Figure 3: 1) dedicated reliable CO_2 storage in a geologic reservoir, 2) CO_2 storage as a co-product of EOR using a historical average for CO_2 utilization and 3) CO_2 storage as a co-product of EOR using *double* the amount of CO_2 typically used for EOR.

The maximum amount of *net* CO_2 removal is achieved in scenario 1 (geologic storage), where nearly 100 percent of the CO_2 delivered from DAC is stored underground, less a marginal amount of direct and embodied emissions associated with materials and energy required in injection. Historically, traditional EOR uses on average 0.5 tCO_2 per barrel of oil produced (Scenario 2). At this rate of utilization, the total emissions associated with combustion of the produced oil, refining, transport and from other contributions is *greater* than the amount of CO_2 stored, leading to net emissions (i.e., there is no net CO_2 removal).

In the final scenario, the amount of CO_2 used for EOR is doubled to 1tCO_2 per barrel of oil produced. Since a greater amount of CO_2 is stored per unit oil, the amount stored is greater than the combined emissions from oil combustion, refining, transport and other sources. The result is net negative emissions. In each of these scenarios, it is assumed that the CO_2 is sourced from

FIGURE 3: ILLUSTRATION OF THREE PATHWAYS AFTER CARBON REMOVAL FROM DAC



Net negative carbon balance over the entire lifecycle (left) with dedicated storage, storage coupled to CO_2-EOR for 1.0 tonne of CO_2 stored er barrel of oil (bbl) produced (middle) and 0.5 tCO_2/bbl oil being the conventional average of today (right).

DAC, which would result in the most significant impact. If, however, the CO_2 was sourced from point-source emitters (i.e., natural gas-fired power plant), net negative emissions would not be possible, but rather avoided emissions may be possible.

Unfortunately, 84 percent of the CO_2 used today is sourced from natural reservoirs (Kuuskraa and Wallace 2014; IEA 2009; Kallahan et al. 2014). In other words, of the 72 $MtCO_2$ used in the U.S. per year for EOR, roughly 60 $MtCO_2$ are sourced naturally, rather than anthropogenically.

It is important to recognize that although the route that involves dedicated storage results in maximum CO_2 removal, it does not provide the revenues that EOR does. In the 1 tCO_2/bbl scenario, there is the potential to produce oil with a reduced footprint (if the CO_2 is sourced through avoided emissions) or even the potential to produce neutral or negative oil (if the CO_2 is sourced from air). Hence, if alternative approaches to the production of liquid fuels, such as biofuels or synthetic fuels using CO_2 and green hydrogen as feedstocks, are not adequate to meeting global society's needs, this approach may ultimately play an instrumental role in closing this gap.

STORAGE OPTIONS

The permanence of CO_2 storage via the different negative emissions approaches varies depending on if the sink is biological, mineral, or coupled to geologic storage. This distinction has become evident through the recent forest and bushfire events of California and Australia (Chow 2020; Barboza 2019).

It was estimated that roughly 1 $GtCO_2$ was emitted into the atmosphere from Australia's recent bushfires in 2019–2020. In 2018 alone, the equivalent of 15 percent of California's CO_2 footprint was emitted from forest fires in that year (Perry et al. 2019). Although these natural sinks represent a significant portion of storage, as climate change persists, the risk of these areas turning into CO_2 sources increases.

The permanence of depleted oil and gas reservoirs has been demonstrated over and over again with CO_2-EOR practices, with the first commercial-scale project taking place in 1972 in the Permian Basin. The scale of reliable CO_2 storage in geologic formations however needs to increase by 100 to 1,000 times what it is today in order to sequester CO_2 sourced from point-source emissions, BECCS, and DAC, collectively producing a gigatonne market of CO_2 that will require permanent storage.

In addition to depleted oil and gas reservoirs, saline aquifer formations are also contenders for storage, but additional characterization needs to take place to determine the most effective sites for the gigatons of storage required to meet climate goals.

THE GIGATONNE CHALLENGE

The term "learning by doing" was coined after the pioneering work of the aeronautical engineer Thomas P. Wright (1936), who discovered that the average man-hours necessary to manufacture a given model of Boeing aircraft reduced in a systematic way given each unit produced. Existing policies such as LCFS and 45Q will help with the scale-up of carbon capture technologies including DAC, but deployment needs to begin at scale today. Through increased deployment and learning by doing, lower costs could be realized.

Climate models are including these technologies to play a role on the gigatonne scale by mid-century, yet today reliable storage is only on the millions of tonnes scale and DAC, in particular, on the kilotonne-scale. The rate of scaling up should be similar to photovoltaics (PV) in the last ten years. PV growth was a result of advanced manufacturing and increases in conversion efficiency (NREL), as well as government policies such as renewable portfolio standards, feed-in tariffs, and a variety of subsidies. These policies accounted for roughly 60 percent of the market growth of PV (Kavlak et al. 2018).

It is clear that policy will be crucial to make larger facilities and standardized manufacturing financially viable for both carbon capture and DAC applications. Currently, the uncertainty regarding extension of the 45Q tax credit for projects beyond 2024 makes the development of future projects economically ambiguous. Nonetheless, the transferability of the 45Q credit makes it possible for DAC companies and EOR or utilization operators to distribute credits and develop early partnerships, while scaling and improving their technologies.

THE PATH FORWARD

Although the costs of point-source capture are less than DAC, it has become increasingly clear that both efforts will be required to meet climate goals. Since a portfolio of solutions will be the only way to meet climate goals, policy may be designed such that the mitigation of emissions is prioritized. Today, point-source capture and DAC qualify for the LCFS and federal tax credit 45Q. More specifically, EOR is the largest market for CO_2 in the U.S. with 84 percent of the CO_2 sourced from the Earth today and an existing market of 72 $MtCO_2$/yr. This equates to a CO_2 utilization opportunity of roughly 60 $MtCO_2$ that could be sourced from either point-source capture of CO_2 or DAC.

The first step toward increasing the scale of reliable storage of CO_2 via EOR should be aligned in a way that disincentivizes the use of natural CO_2 and ultimately transitions away from the extraction of oil to the permanent and dedicated storage of CO_2. Further, if operators can depend on up to \$243/tCO_2 stored in the Earth through EOR, there may be adequate incentive to carry out stacked storage, i.e., coupling dedicated storage of CO_2 to CO_2-EOR projects.

If correctly priced and perhaps even flexibly priced as a function of current oil prices, operators will be inclined to increase the CO_2 stored per barrel of oil produced, i.e., increasing from the historical average of 0.5 tCO_2 up to 1–2 tCO_2 per barrel of oil produced. Over time, one might envision that as policy is further refined and depending on the availability of low-carbon or zero-carbon liquid fuel dependence at that time, oil companies may transition into becoming CO_2 sequestration companies.

Finally, there are companies such as Microsoft, Shopify, Delta, and many others listed in Table 1 of the Appendix (Rathi 2018; Calma 2019; BBC News 2020; Calma 2020) that are aiming to become carbon-neutral by mid-century or sooner. This amibition will likely require some component of negative emissions, since some sectors are simply too difficult to decarbonize today.

By outlining negative emissions pathways, these companies may invest in projects that will assist in offsetting current and potentially historical emissions. However, this is only possible with a policy framework that provides these companies, as well as future companies, with leverage, whether economic or infrastructure based. By creating such policy, there will exist economic incentives to both avoid CO_2 emissions and actively remove CO_2 from air at the tens of gigatonne-scale to meet climate goals.

APPENDIX

TABLE A1: LIST OF COMPANIES ANNOUNCING PLANS TO REACH CARBON NEUTRALITY BY MID-CENTURY IN ADDITION TO THEIR PLEDGE AMOUNT WHEN AVAILABLE

Company	Year to Neutral	Investment Amount	Details of Plan	Notes
Delta	2030	$1 billion over the next decade	Buy emission offsets and invest in more efficient planes, new fuel sources (biofuels) and carbon-capture technologies.	Considering ways to sequester carbon through nature-based solutions like forestry, wetland restoration, and grassland conservation.*
BP	2050		Eliminate or offset all its emissions by 2050—about 415 million metric tons.	CEO offered no details for how BP planned to meet its goal.
Verizon	2035	$1 billion bond	Bond targeting renewable energy, energy efficiency, green buildings, sustainable water management, and biodiversity and conservation, including planting trees and undertaking other reforestation efforts in areas hit by natural disasters.	Pledged to set a Science-Based emissions reduction Target (SBT) by September 2021 to further its commitment to emissions reductions in line with the Paris Agreement.*
Lundin Petroleum	2030	$60 million in a hydropower project in Norway	The company said it would use renewable energy to supply its offshore fields and also adopt carbon offset measures.	—
Repsol	2050	$5.3 billion	Double production of biofuels from vegetable oils and start producing green hydrogen in its refining business.	May additionally offset emissions through reforestation and other natural climate sinks to achieve zero net emissions by 2050. *
Bosch	2020	€2 billion	The company will invest €1 billion buying green electricity, engaging in carbon offset programs, and sourcing power from renewables; and €1 billion to boost in-house energy efficiency.	—
Patagonia	2025	—	Improve efficiency. Switching to Renewable Energy. Recycling.	Patagonia is investing in carbon sequestration projects. Through regenerative organic agriculture and reforestation in particular, Patagonia is looking to expand efforts that capture carbon from the atmosphere and store it deep in the soil.*
Amazon	2040	$100 million	Buying 100,000 electric delivery vans from a start-up, and using 100% renewable energy by 2030.	Amazon will invest $100 million in reforestation projects around the world to begin removing carbon from the atmosphere.*
Bayer	2030	—	Switching to renewable electricity and more efficient processes.	—

*Projects related to carbon offset for being considered “carbon-neutral”

Company	Year to Neutral	Investment Amount	Details of Plan	Notes
AstraZeneca	2015	To $1 billion	Convert to renewable sources for both power and heat and switch to electric cars.	Partner with reforestation organizations and governments to plant 50 million trees over the next five years.*
LG	2030	—	Investing in high efficiency equipment/ facilities and solar power generating systems and increasing purchase of renewable energy in office buildings.	—
PSE&G	2050	$4.3 billion	Continuing using nuclear and will have retired or exited through sales more than 2,400 MW of coal-fired generation.	$2.5 billion for 22 energy efficiency programs. $1.8 billion in 674 MW of solar energy resources.
Mercedes-Benz	2039	—	Electric cars powered by renewables and use wind to meet the majority of the power consumption. Mercedes will also work with its suppliers to decarbonize the production process for the car components than they purchase.	The company is additionally investing in scaling up recycling solutions, in a bid to recycle 85% of the materials used in each of its vehicles at the end-of-life stage within the next two decades.
Daimler	2030	$11.7 billion	To have electric models make up more than half of its total car sales, including all-electric models and plug-in hybrids. They also aim to electrify its vans, trucks and buses, by rapidly transferring technology between the divisions with a focus on battery electric mobility, but is also pursuing other solutions, including fuel cells or even eFuels as an option.	—
Altana	2025	—	Complete sourcing all of its power from renewables this year (2020). It will finance “equivalent climate protection projects” to offset natural gas consumption where it is unavoidable and will also offset CO_2 emissions arising from necessary business trips, company cars, and the transport of goods.	—
BASF	2030	—	The company will shift to CO_2-neutral power in energy procurement, enhancing operational excellence and further measures to be developed at a later stage (e.g., use of offsets).	—
Monsanto	2021	—	Creating carbon-neutral crop production practices.	—

*Projects related to carbon offset for being considered “carbon-neutral”

Company	Year to Neutral	Investment Amount	Details of Plan	Notes
Volkswagen	2050	€30 billion	Electrification of the fleet by 2050 and using renewable energy for its operations.	—
Siemens	2030	€100 million	Siemens is focusing on four levers: energy efficiency, decentralized energy systems, intelligent e-mobility solutions and the purchase of clean electricity.	Expected annual savings of about €20 million from 2020 onward.
Maple Leaf	2019	—	Lighting retrofit program at all of its facilities, projects to capture excess heat produced by its equipment, partnering with companies that turn organic waste into energy and the development of a utility management system that allows it to track its energy usage.	Carbon offset: The projects will support wind energy, forest protection and re-forestry, as well as the reduction and recovery of methane gas emissions.
Google	2017	$2 billion	Energy efficiency, renewable energy procurement, and, when necessary, carbon offsets.	To date (2018), Google has signed contracts to purchase the output of more than 3 GW of renewable energy across 26 projects, making it the largest corporate purchaser of renewable energy in the world and resulting in more than $3.5 billion USD of total investment.
Shopify	2019	$5 million annually	In 2018, decommissioned all of their data servers and shifted entirely to Google Cloud to power our platform. With this change, their platform is now carbon neutral, as Google matches 100% of the energy consumed by Google Cloud with renewable energy.	Shopify is committed to investing at least $1 million USD each year into carbon sequestration.
Stripe	2018	$1 million annually	Improving energy efficiency, clean energy purchasing where possible, and advocating for the same from the partner companies.	It will allocate at least $1 million each year on negative emissions technology by purchasing tons of carbon dioxide removed from the atmosphere.
Microsoft	2030	$1 billion	Balancing its emissions, for example by removing a tonne of carbon from the atmosphere for every tonne it produces; offsetting its emissions, for example by investing in projects that reduce emissions elsewhere in the world; not releasing greenhouse gases in the first place, for example by switching to renewable energy sources.	Project interests include seeding new forests and expanding existing ones, soil carbon sequestration, direct air capture, and bio-energy with carbon capture.

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