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Developing a Portfolio of Negative Emissions Technologies from Point-Source to Direct Air Capture

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ABSTRACT

The only way we can achieve the IPCC's goal of limiting warming to 1.5ºC is through a massive expansion of negative emissions technologies (NETs), chiefly carbon dioxide removal (CDR). To date, point-source carbon capture has been the most widely recognized and deployed form of CDR, but it is limited in its efficacy in achieving negative emissions. Direct air capture (DAC), a newer form of CDR, captures excess CO2 in the lower atmosphere, as opposed to capturing CO2 directly from the emission source. If the captured CO2 is stored or sequestered, the process involved in DAC allows for true negative emissions, as opposed to point-source CDR which can only achieve carbon neutrality at best. The potential for DAC presents significant opportunities for large-scale CDR, but point-source carbon capture will still be essential and applicable in sectors where decarbonization is difficult. As the global community ratchets up decarbonization efforts, a combination of DAC and point-source will prevent even further catastrophic climate change in the future.

The climate crisis is the most pressing issue plaguing society today, and overcoming it will require unprecedented international cooperation, innovation, and adaptation. Climate scientists around the world agree that carbon dioxide removal (CDR) must play a central role in our efforts to reduce the most extreme impacts of climate change. In 2018, the IPCC reported that "limiting warming to 1.5ºC will require the use of 'negative emissions technologies' (NETs) – methods that remove CO2 from the atmosphere" (Harrison, 2019). However, the form of CDR that receives the most attention, point-source carbon capture, is very limited in its ability to achieve the level of carbon sequestration now required to meet our goals. Direct air capture (DAC), a newer form of CDR, is better equipped to lower atmospheric CO2 in the long-term as it can sequester CO2 straight from the atmosphere. In order to adhere to the path of adaptation and mitigation outlined by the global community of climate scientists, DAC systems will need to be implemented alongside point-source carbon capture systems.

CDR technologies have been around for exactly half a century, yet the history surrounding their funding and deployment is not what it may seem. Point-source carbon capture sequesters CO2 directly from the emission source in its gaseous form. The first point-source plant was installed by Terrell Oil & Gas in 1972 (Center for Climate and Energy Solutions, 2021) for the purpose of enhanced oil recovery (EOR), a method of injecting gaseous and pressurized CO2 into oil wells to reduce the oil's viscosity, making the oil cheaper and easier to extract. In fact, for the first 20 years of its existence, point-source carbon capture was used solely for the purposes of emitting more fossil fuels, either through EOR or by diverting captured CO2 for industrial purposes. It wasn't until 1996 that the first carbon capture and storage plant utilized point-source for the purposes of carbon sequestration. Sleipner Carbon Dioxide Storage Facility offshore of Norway was the first project to store captured carbon in geologic reservoirs (Center for Climate and Energy Solutions, 2021).

In addition to point-source carbon capture, DAC is an essential technology to lower future warming. DAC utilizes a mechanism by which excess CO2 is captured directly from the atmosphere. In DAC systems, common chemicals are used to react selectively with CO2 molecules, trapping them, while other components in the air are able to pass (Lebling et al., 2022). The chemicals used either make up liquid solvents or solid sorbents, to which heat is then applied in order to separate the CO2. While liquid solvent systems require a temperature of 900ºC in order to separate captured CO2, solid sorbent systems typically only need between 80-120ºC, meaning "that solid sorbent systems can use waste heat or renewable energy, while solvent systems currently rely on natural gas with [point-source] carbon capture and storage" (Lebling et al., 2022). After heat is applied, the solvents or sorbents can then be reused in the system.

Due to the nature of DAC, there are no locational limitations, which makes deployment extremely flexible. Unlike point-source carbon capture, DAC has the potential to sequester more CO2 than it emits because it captures pre-existing CO2 from the atmosphere, as opposed to capturing CO2 as it's being emitted. The captured CO2 can either be permanently stored (e.g., underground in geologic reservoirs), resulting in a carbon *negative* system, or transformed for a different use (e.g., fertilizers, EOR, etc.), leading to a carbon *neutral* system. For comparison, efficient point-source systems aim to collect ~90% of the CO2 emitted directly at its source (Moseman et al., 2021), and therefore are currently unable to even reach carbon neutrality.

On a technological readiness scale from one to nine, DAC is currently quoted as a six, "meaning it's still in the large-scale and prototype phase, not yet ready for full commercial deployment" (Lebling et al., 2022). This stage allows for significant development in technology and cost efficiency through experimentation and innovation. Three groups currently pioneering this work are Climeworks, centered in Switzerland, Global Thermostat in the US, and Carbon Engineering in Canada (Lebling et al., 2022). Of these three groups, Climeworks and Global Thermostat utilize solid sorbent systems, whereas Carbon Engineering uses liquid solvents. Since solid sorbents require less heat energy, Climeworks is able to power their plants entirely through non-fossil fuel energy sources (e.g., geothermal and waste heat), while Carbon Engineering relies on a combination of renewable sources and natural gas. Climeworks currently has 15 installed plants throughout Europe with a net capturing capacity of approximately 6,000 tCO2/year. Global Thermostat has two plants in the US with a collective capacity of 1,500 tCO2/yr, while Carbon Engineering currently has a pilot plant in Canada and is developing a 1MtCO2/yr plant (1 million tons CO2/yr) in the US (Climeworks, 2022). For scale, scientists around the world agree that "up to 10 GtCO2 will need to be removed annually from the atmosphere by 2050, with increased removal capacity up to 20 GtCO2 per year by 2100" (World Resources Institute, 2020). This extreme necessity (1 Gt = 1,000 Mt) confirms that while DAC may not be the sole mode for CDR, it certainly is an essential one.

The condition of our atmosphere is a public good – it can't be bought or sold but is essential to human well-being and survival. Because there is currently little to no profit to be made by capturing and sequestering CO2, much of the history of point-source carbon capture is closely tied to fossil fuel interests. Many of the profitable applications of point-source, such as EOR and the production of synthetic fuels, severely limit the technology's effectiveness in ultimately reducing GHG emissions. Therefore, it is vital to establish a new, viable economic model for storing the CO2 captured from either point-source or DAC systems. Climeworks, for example, utilizes a portion of their captured CO2 for the production of various building materials like cement (Fairs, 2021). Since 40% of global emissions come from the construction sector, the use of captured atmospheric carbon in building materials could be critical to transforming the industry and reducing GHG levels (Fairs, 2021). With regard to legislation, there are already policies in place to support groups dedicated to capturing and sequestering CO2. However, in order to achieve the full potential of both point-source and DAC technologies, stronger and more expansive policies to support and incentivize the storage of captured CO2 must be implemented – this will ultimately prevent the most extreme impacts of future climate change.

Carbon Engineering is creating the world's first large-scale DAC plant capturing 1 MtCO2/yr (Carbon Engineering, 2022)– this could not have occurred without significant support from local and federal policies. For example, California's Low Carbon Fuel Standard, which offers a credit of $200/tCO2 in or out of California, has been crucial in funding the construction of the plant (Lebling et al., 2022). On a federal scale, additional policies in support of DAC include the 45Q Tax Credit and Bipartisan Infrastructure Law. The 45Q tax credit offers $35-50/tCO2 captured through DAC or point-source, providing $50/tCO2 if it is sequestered and $35/tCO2 if it is diverted for another use, and several expansions of 45Q including increased credits and timelines have been proposed (Lebling et al., 2022). Additionally, the Bipartisan Infrastructure Law offers various funding opportunities for DAC. Foremost, the law allocates $3.5 billion to four regional 1 MtCO2/yr DAC hubs, and $4.6 billion to develop supporting infrastructure such as CO2 pipelines and geologic sequestration (Lebling et al., 2022). The law also allocates $100 million as a commercial prize to a group with DAC technology as well as “a front-end engineering and design program for CO2 transport infrastructure required to enable carbon capture, utilization and storage deployment” (The Office of Fossil Energy and Carbon Management, 2022), and $15 million as a pre-commercial DAC prize. Finally, the federal government also funds research and demonstration of different CDR methods including DAC through the Department of Energy. This funding has increased significantly from less than $10 million in the years 2009-2019, to $129 million in the most recent fiscal year 2022 (Lebling et al., 2022). Beyond federal and state policy, corporate investments have also contributed to DAC funding, with companies such as Stripe, Shopify, and Microsoft devoting hundreds of millions of dollars to CDR technologies such as point-source and DAC.

The climate crisis demands that we, as a global community, engage a number of both adaptation and mitigation strategies. Adaptation describes efforts to make our current systems and processes more sustainable (e.g., resilient infrastructure), while mitigation denotes efforts to directly reduce the severity of current and future climate change (e.g., decarbonization). Through this lens, point-source and DAC must go hand-in-hand, with point-source used to adapt our current systems and DAC used to mitigate overall warming. In addition to DAC, other mitigation techniques include *natural climate solutions* such as reforestation, which employs a similar process of capturing excess atmospheric carbon as well as introducing a host of other ecological benefits. As governments and corporate groups continue to increase their support for DAC, the single greatest danger of technology is its potential to pull attention away from decarbonization efforts. DAC has the exciting potential to help us reach carbon negativity, but that can only occur if we also rapidly decarbonize our systems and deploy point-source in sectors where that may be difficult. In an ideal future, point-source systems would only be employed in sectors where the burning of fossil fuels is an absolute necessity (e.g., steel and cement) and DAC would be implemented on a worldwide commercial scale with a capacity of capturing ~1GtCO2/yr. As we ratchet up our decarbonization efforts, we must also pour resources and attention into the further development of negative emissions technologies like DAC, meaning greater funding and legislative incentive, research and innovation from the private sector, and a more defined and contextualized timeline of action.

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