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Topic: Direct Air Capture Technology

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Greenhouse gases, like CO_2, trap heat from the sun within Earth's atmosphere, increasing global warming; since 1970, average global temperature has increased by 0.17 degrees Celsius per decade [1]. According to the World Health Organization, air pollution contributes to an estimated 4.6 million deaths every year [2]. Without some significant method of control or reversal, greenhouse gases and pollution will destroy our world in the form of stratospheric ozone depletion and global warming. Hotter temperatures have a negative effect on public health, speeding up the chemical reactions that produce air pollutants like fine particulate matter and ozone [3]. Air pollution is affecting human life, slowly impacting the rise of global temperatures, a trend which will continue if left unaddressed. Solar power, hybrid vehicles, and other green movements may not be enough to reverse the damage that is done, but new, negative-emission technology would be a feasible solution if sufficient funding became available. With several different prototypes and functional models out there, Direct Air Capture (DAC) is arising as a promising solution to climate change, with its ability to remove industrial amounts of CO_2 from the air for sequestering, and other purposes. DAC is a feasible, effective solution that needs to be implemented worldwide to reverse the daunting effects of air pollution and global warming on a large scale.

DAC, along with geo-engineering technologies like enhanced weathering and ocean fertilization, falls into a category of Carbon Dioxide Removal (CDR) [4]. CDR is a technique which differs from regular atmospheric emission control. The focus of this new approach is to decrease the concentration of carbon dioxide in the air, aiming to achieve lower atmospheric levels than before. Earlier methods were only able to reduce the number of emissions from point sources, like power stations, slowing the increase of air pollution [4]. "DAC is not built to capture CO_2 from a particular gas stream. Therefore, it has the advantage of not being causally linked to the existing energy infrastructure that generates CO_2, as other CCS technologies do, and it allows achieving mitigation irrespective of where and how emissions occur [5]." This is unique within CDR technologies, establishing DAC as an advantageous technique. At this point, nothing else is as quantitatively promising as an effective form of CDR. DAC is still in its infancy but, hypothetically, it would be able to remove several tons of carbon dioxide from ambient air every day [4].

DAC technology can remove CO_2 directly from ambient air using chemicals (e.g. sodium hydroxide) in a tower-like structure [5]. Many different manufacturers are working on their own DAC methods, each with a unique process. Although work in this industry in in its infancy, "Researchers are working on direct air capture with a sodium hydroxide (lye) solution and then heating it to release the CO_2, allowing for continuous and lower cost large-scale operation" [4]. Most DAC prototypes use a chemical process involving a hydroxide that will – through specific interactions – produce pure CO_2, which may be used as "a low-carbon alternative crude product that can be refined for fuel" [4]. Figure 1 illustrates a visual example of a DAC process, as demonstrated by the model from "Carbon Engineering" [6]. Most DAC configurations are flexible to accept power from substitutable clean electricity, making them clean and sustainable to avoid emissions from natural gas usage [6]. This is an important quality for such a technology; if it were to produce emissions from natural gas usage, the efficiency of CO_2 removal would not be as significant.

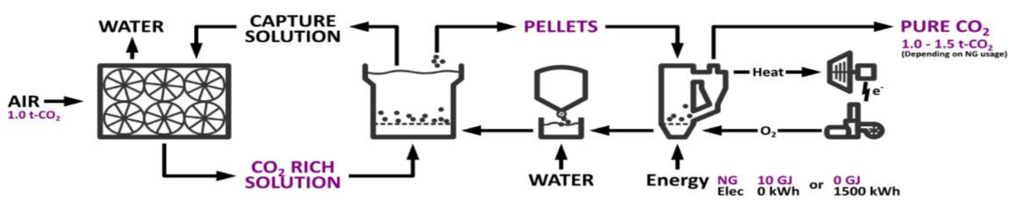

Figure 1. "Carbon Engineering" model process of DAC [6].

The chief operating officer, Dominique Kronenberg, of Climeworks – a company with a unique DAC process – explained reasonable information regarding relative cost of air capture: "The American Physical Society (APS) estimated that on a large-scale CO_2 could be captured for $600 per tonne" [7]. This brings up the big question of price, which is the biggest topic of discussion for DAC implementation. It's more expensive than other methods, and at this point, it "does not challenge post-combustion capture from point sources", says Professor Frank Zeman, professor of chemistry and chemical engineering at the Royal Military College of Canada, which are estimated at $80/t$CO_2$ [8]. These statistics, however, do not consider cost and duty of transportation for point source carbon capture technology. DAC can be operated anywhere in the world, capturing carbon from ambient air near stationary plants. The implementation of DAC relies now on "global cooperation on a stringent climate objective" [8]. When climate change identifies itself as an immediate global crisis, it is more likely that we will see large-scale global operation of DAC. Kronenberg, like most geo-engineers, says they "expect to equal that and eventually get costs down well below that" [7], referring to his statement regarding the cost estimate from APS. Many, like Kronenberg are optimistic for the future of DAC in the shared belief of its future necessity and latter development, due to the observable effects of air pollution and global warming from greenhouse gases like CO_2.

Kronenberg's company, Climeworks, has become the "first ever to capture CO_2 at industrial scale from air and sell it directly to a buyer" [9]. Plant developers say that it will capture CO_2 levels equivalent to that of 200 cars – approximately 900 tons – annually, and the gas will be piped to help grow vegetables [9]. Although this amount is less than that captured at large fossil fuel sites, Climeworks says that it is the first step for them in their goal to "capture 1 percent of the world's global CO_2 emissions" [9]; their objectives are geared to keep global temperature rise below 2 degrees: an international standard. If international focus on such technology were to increase, more plants would contribute with statistics that would continue to improve with technological developments, further contributing to such an objective. The Climeworks plant stands "on top of a waste heat recovery facility that powers the process", making it self-sufficient, sending captured gas through pipelines to a 4-hectare greenhouse that grows vegetables [9]. The team at Climeworks intends for this plant to be subject of a three-year demonstration project that will provide data to support reliable calculations for larger projects [9]. The benefits of such plants would be astounding following the large-scale implementation, with the mitigation of air pollution and climate change in mind, despite initial concerns with cost.

According to the National Oceanic and Atmospheric Administration (NOAA), "all 16 years of the 21st century rank among the seventeen warmest on record…The five warmest years have all occurred since 2010" [1]. This cannot be ignored forever, as numbers will continue to rise with increasing levels of pollution making things worse. The same model projection claims that by 2030, warming from the greenhouse gas effect will begin to "overcome the oceans' thermal inertia, and projected temperature pathways [will] begin to diverge" [1]. The ocean's slow heating – from greenhouse gases – will likely lead to several degrees of increase in temperature by the end of this century [1]. This is a scary feat for most; however, with continuous funding and attention, DAC may be able to halt such phenomena.

With enough resources, numerous plants similar – and more efficient – to that of aforementioned models could be implemented to reverse current predictions of global temperatures, in regard to human health and longevity. DAC could be the answer the world is searching for to relieve it of inevitable pollution, ozone depletion and global warming. Greenhouse gases could be contained, human longevity could be preserved, and global warming could be stopped. Only after accepting initial financial constraints, though, will we be able to overcome such dangers with an impactful solution.

References:

[1] L. Dahlman. (2017, September). “Climate Change: Global Temperature”, *ClimateWatch Magazine* [Online]. Available: https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature [Accessed 2017, November].

[2] “Air Pollution”, *ScienceDaily* [Online]. Available: https://www.sciencedaily.com/terms/air_pollution.htm [Accessed 2017, November].

[3] University of North Carolina at Chapel Hill. (2017, July). "Climate change expected to increase premature deaths from air pollution: Most comprehensive study yet on climate change, air quality and premature death.", *ScienceDaily* [Online]. Available: https://www.sciencedaily.com/releases/2017/07/170731114536.htm [Accessed 2017, November].

[4] “Carbon Dioxide Removal”, *Wikipedia* [Online]. Available: https://en.wikipedia.org/wiki/Carbon_dioxide_removal [Accessed 2017, November].

[5] C. Chen and M. Tavoni, "Direct air capture of CO2 and climate stabilization: A model based assessment,” *Climatic Change*, vol. 118, *(1)*, pp. 59-72, 2013. Available: https://link-springer-com.ezproxy.library.uvic.ca/article/10.1007%2Fs10584-013-0714-7 [Accessed 2017, November].

[6] Carbon Engineering, “Direct Air Capture”, *Carbon Engineering* [Online]. Available: http://carbonengineering.com/about-dac/ [Accessed 2017, November].

[7] R. Schiffman. (2016, May). “First commercial carbon-capture plant set to open in Switzerland”, *New Scientist* [Online]. Available: https://www.newscientist.com/article/2091214-first-commercial-carbon-capture-plant-set-to-open-in-switzerland/ [Accessed 2017, November].

[8] F. Zeman, "Reducing the Cost of Ca-Based Direct Air Capture of CO2", *Environmental Science & Technology*, vol. 48, *(19)*, pp. 11730-11735, 2014. Available: http://pubs.acs.org.ezproxy.library.uvic.ca/doi/10.1021/es502887y [Accessed 2017, November].

[9] C. Marshall. (2017, June). “In Switzerland, a giant new machine is sucking carbon directly from the air”, *Science* [Online]. Available: http://www.sciencemag.org/news/2017/06/switzerland-giant-new-machine-sucking-carbon-directly-air [Accessed 2017, November].