Assessment Ameliorating Global Warming Though Direct Air Capture

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Abstract. DAC as a solution to negatively increase carbon dioxide in the atmosphere. People are paying more and more attention to this scheme. Despite technological breakthroughs in the past decade, the current principles, limitations and effects of DAC are poorly understood. This paper through collation, literature review and other methods to describe the realization principle of DAC and the expected effect of DAC. The paper finds that there is a problem with DACs, which is the usage of CaCO3 to make use of electricity when it needs to heat and blow air to contactors, because that way would generate abundant CO2 and the DAC would be advanced in its efficiency as long as the problem is solved. Besides, compared with other methods of absorbing carbon dioxide, the cost of DAC is very low, and it can absorb the carbon dioxide released from different places, such as car driving, which also accounts for a large part of the carbon dioxide emissions. Thus, the use of DAC currently is of great significance.

Keywords: global warming · direct air capture · carbon dioxide · chemistry

1 Introduction

The result of the overuse of fossil fuels in the past, especially during the industrial revolution, is very grievous global warming today. When people burn fossil fuel unlimitedly, the temperature of the atmosphere rises as a result of the increasing concentration of greenhouse gases. To be more specific, CO2, the main substance that causes global warming in the atmosphere, has rapidly increased from 280 ppm before the industrial revolution to 403 ppm in 2016, with an annual growth rate of 2 ppm. [1].

Direct air capture (DAC) has received a lot of attention in the mainstream because it is impossible to achieve the negative growth of CO2 in the atmosphere, that is, reversing the increase in CO2 concentrations in the atmosphere associated with fossil fuel use since the Industrial Revolution, thus contributing to society. Remove carbon dioxide directly from the atmosphere. Because direct carbon capture now requires the use of electricity to decompose calcium carbonate so that the calcium oxide feedstock can be reused, the major problem facing direct carbon capture is how to obtain electricity in a green way. ([2] Because the absorption of DAC is extremely inefficient, this paper will also focus on the sorbents used before the reaction process. This increases the concentration of carbon dioxide in the air and improves the efficiency of the DAC. The author will

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introduce three different adsorbents and make some speculations about future adsorbent choices. The aims of this paper are twofold: firstly to discuss the limitations of the DAC (technology and economic); secondly, to find possible solutions to these limitations. It hopes to provide insightful suggestions for the development of this field.

2 Global Warming

According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [3], the global average annual temperature has risen by around 0.8 °C since observations began in the middle of the 19th century. However, the global warming trend has slowed down significantly in the last decade. British meteorologist Knight had raised this question as early as 2009. They pointed out that compared with the period from 1979 to 1998, the global surface temperature increase rate was significantly lower in the 10 years after 1999 [4]. In other words, global warming is slowing down or stagnating now.

Temperature observation data from various sources show that [5], the surface temperature of the earth's rising trend was 0.07 ± 0.08 C (10a) -1 from 1997 to 2013, which was 0.16 0.02 C (10a) -1 year higher than the trend in the past 50 years. It is much lower and even lower than the IPCC's 5th Assessment Report's estimate of the changing trend [0.2 C (10a)-1]. Although there is some uncertainty in the rate of global temperature increase, from the perspective of global mean surface temperature, the global warming trend has stalled (Fig. 1a, b).

Although the rate of global warming has slowed over the past decade, many of the observed changes in the climate system since the 1950s are unprecedented over decades or even millennia. For example, sea ice and snow cover still remain. During melting, the ocean is still absorbing heat in a net and the average global sea level is still rising [6]. A number of phenomena suggest that the long-term trend in global warming has not completely stopped, and most importantly, global surface temperatures are still high (Fig. 1a). For example, the global mean surface temperature reached two consecutive record highs in 2014 and 2015 [7]. The UK Met Office reported that both observational data and numerical simulations indicated that similar global mean surface temperatures The period in which the trend of change is close to zero in a period of time is not an exception. It occurs in both past observations and future projections, and roughly occurs at least twice every century (such as the 1900s and 1960s of the last century; Fig. 1b). Therefore, the stagnation of temperature trends is not unprecedented but may be a temporary phenomenon [6].

The "Report of the Intergovernmental Panel on Climate Change (IPCC) on the Impacts of Global Warming of 1.50 °C beyond pre-Industrial Levels" (2018) shows that we should keep global warming to 1.50 °C by the end of the 21st century to prevent catastrophic and disastrous consequences. This entails a 45% reduction in CO2 emissions by 2030 and a net zero emission by 2050. Whereas the IPCC claims that this objective is achievable, achieving it will necessitate immediate and extraordinary social and economic change.

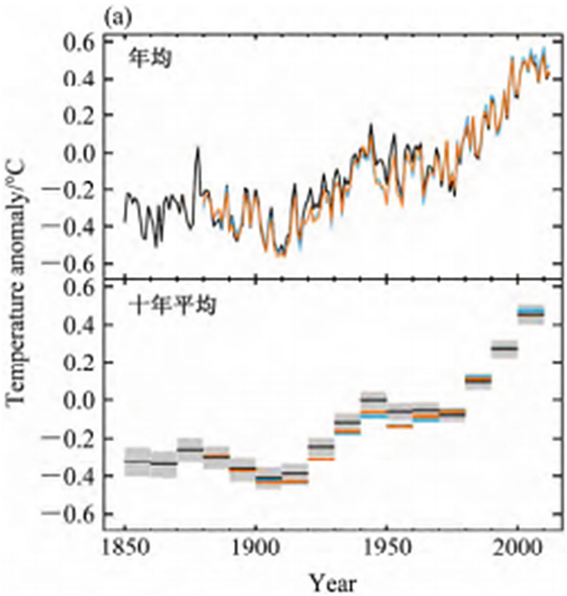

Fig. 1. (a) Observed global mean land and sea surface temperature anomalies (1850–2012) from three datasets (top: annual mean, bottom: decadal mean, including one dataset (black) Uncertainty estimates are relative to the 1961–1990 average for each distance (Su Jingzhi, Wen Min, Ding Yihui, et al. 2016. Hiatus of global warming: A review [J]. Chinese Journal of Atmospheric Sciences (in Chinese), 40 (6): 1143–1153, https://doi.org/10.3878/j.issn.1006-9895.1512.15242.)

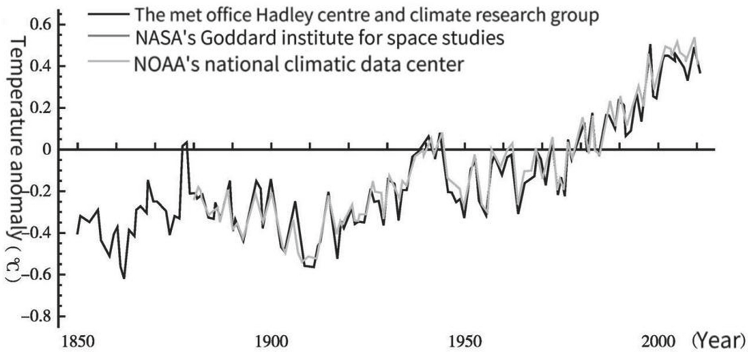

Fig. 2. (b) The anomaly change of the global annual average temperature from 1850 to 2012 (relative to the 1961–1990 average) (Quoted from the 2012 Statement on the State of the Global Climate issued by the World Meteorological Organization) (Su Jingzhi, Wen Min, Ding Yihui, et al. 2016. Hiatus of global warming: A review [J]. Chinese Journal of Atmospheric Sciences (in Chinese), 40 (6): 1143–1153, https://doi.org/10.3878/j.issn.1006-9895.1512.15242).

3 Direct Air Capture

We possess a variety of alternatives for absorbing gases such as carbon dioxide. For instance, carbon dioxide produced by industry can be immediately absorbed at point pollution sources, or greenhouse gas emissions from typical power plants can be directly absorbed by cement factories. These plants, meanwhile, are frequently too old to be revived. Furthermore, even in plants with CO2 removal systems, it is extremely difficult to capture all of the CO2 produced; the typical CO2 capture rate for these plants is between 50% and 94 percent [7]. Furthermore, long-distance air and ocean travel, as well as ordinary transportation, account for half of world emissions. Traditional CO2 collecting applications are incapable of solving these issues. [8] Formalized paraphrase As a result, we must devise an independent and effective way to deal with this problem.

The absorption and regeneration cycles make up the entire direct air capture process. The first cycle is absorption, in which the surrounding air is pushed into contact with a discharge of NaOH (NaOH) solvent in the absorption column through a fan or normal air flow. When CO2 molecules combine with NaOH, sodium carbonate (Na2CO3) is formed (1). At room temperature and pressure, absorption occurs. The carbon dioxide-depleted gas passes through the column after this solution is transferred to the regeneration cycle. Solid calcium carbonate (CaCO3) is formed in the second cycle by mixing Na2CO3 with calcium hydroxide (Ca(OH)2) in a causticiser unit, and NaOH is regenerated (2).

The NaOH is returned to the contactor, where it will begin a new absorption cycle. Simultaneously, the CaCO3 is heated to roughly 900 degrees Celsius in a kiln (calciner unit) to liberate carbon dioxide, which is the most energy-intensive phase. The entire heat demand, when paired with the heat integration level, is estimated to be between 1420 and 2250 kWh ht CO2. Calcium oxide (CaO) and a pure CO2 stream are the end products of this process (3). CO2 is collected by the oil drain, and CaO is combined with water to regenerate Ca(OH)2 (4).

$$\text{Contactor} \quad 2\text{NaOH} + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3 + \text{H2O} \tag{1}$$

$$\text{Causticiser} \quad \text{Na}_2\text{CO}_3 + \text{Ca(OH)}_2 \rightarrow 2\text{NaOH} + \text{CaCO}_3 \tag{2}$$

$$\text{Calciner} \quad \text{CaCO}_3 + \text{heat} \rightarrow \text{CaO} + \text{CO}_2 \tag{3}$$

$$\text{Slaker} \quad \text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 \tag{4}$$

The system needs power to blast air into the contactors, spray water outside, and *transport solution from unit to unit*, in addition to heating. This electricity is estimated to be between 366–764 kW/tCO2 in the literature. Natural gas has been utilized in the past to supply heat, but this is not a long-term option. Providing 2000 kWh of high heat by natural gas oxyfuel burning at 90% efficiency while absorbing 1 ton of ambient CO2 will result in 0.44 tons of CO2 emissions based on natural gas alone, without taking into account its life cycle emissions. Despite 0.5 tons of carbon dioxide being emitted for every ton of atmospheric carbon dioxide absorbed, this carbon dioxide can be recovered and used as a source for other uses.

However, they wind up in the atmosphere after some recycling. Additionally, this approach would significantly raise the cost of direct CO2 capture. Even if SNG-based CO2 has a completely closed cycle and no additional energy is required for CO2 recovery, converting 0.5 t of fuel-based CO2 to synthetic natural gas (SNG) requires approximately 4400 kWh to produce the necessary hydrogen, according to 2030 Electrolyser Technology [8].

It seems apparent that by the middle of the twenty-first century, we will require a huge number of major DAC systems to meet the Paris Agreement's targets. By 2020, 2030, 2040, and 2050, 3470,4798,15402 million tons of CO2/A DAC capacity will be required, correspondingly. The state of the art in terms of energy systems is classified through a survey of the DAC technical literature. A technical and economic examination of the two primary direct air capture systems now on the market, which are characterized by high temperature aqueous solution (HT DAC) and low temperature solid sorbent-based direct air capture technologies (LT DAC),

The following conclusions can be drawn: while the energy demand of a low-temperature DAC system is larger, its overall energy requirement can be supplied at about the same cost as a high FLh, because a large portion of the energy demand can indeed be fulfilled by heat pumps for reasonably affordable low-grade heat. Moreover, while both technologies have the same amount of capital expenditure, low temperature DAC technology is the most cost-effective alternative present and potential due to its ability to extract waste heat from other suppliers. The LT DAC system is also highly adaptable and does not require external water.

The conservative scenario (CS) assumes 50% implementation of needed DAC systems and a 10% learning rate of DAC expenditure, while the base case scenario (BS) assumes 100% implementation and a 15% learning rate of DAC capex.

4 Conclusion

DAC, in our opinion, offers enormous promise for reducing carbon emissions and achieving carbon neutrality. However, DAC has a lot of room for growth. We ought to construct more green energy supply devices, for example, to lay the groundwork for widespread use of DAC. Furthermore, we must improve the effectiveness of DAC. We can make improvements to the sorbents we utilize. constructing a variety of DAC sorbent materials that are low-cost, high-throughput, and high-selectivity.

In conclusion, compared with other methods of absorbing carbon dioxide, the cost of DAC is very low, and it can absorb the carbon dioxide released from different places, such as car driving, which also accounts for a large part of the carbon dioxide emissions. But DAC also faces many huge problems, such as how to find a stable, clean source of electricity that is used to blow air into the contactor. Discovering a catalyst that reduces the heat used to decompose CaCO3, promoting the construction of green power plants, and utilizing more efficient sorbents to absorb CO2 from the air can directly ameliorate DAC and facilitate the utilization of DAC.

Through observations, meteorologist Etienne Capigian of the French Meteorological Agency pointed out that the current temperature in Antarctica is minus 11.5 degrees Celsius, which is 40 degrees Celsius higher than the historical period. Global warming must be a significant reason for this phenomenon. It also shows how important it is for us to actively address global warming.

As for the limitations of this paper, they lack further research of experimental steps and the devices' selection that make the whole process more understandable, which can also be advanced in future studies.

References

1. IEA, CO2 Emissions from Fuel Combustion. Statistics. OECD/IEA, Paris. 2017, Available at: https://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustionHighlights2017,pdf. (Accessed 25 May 2018).
2. IOP Publish,Environ. Res. Lett, Assessment of reasonable opportunities for direct air capture, 2017. https://doi.org/10.1088/1748-9326/aa6de5.
3. Knight J, Kennedy J J, Folland C, et al., Do global temperature trends over the last decade falsify climate predictions? [J]. Bull. Amer. Meteor. Soc., 2009, 90 (8): S22 S23.
4. Fasihi, M., Bogdanov, D., Breyer, C., Long-term hydrocarbon trade options for the Maghreb region and europe - renewable energy based synthetic fuels for a net zero emissions world. Sustainability, 2017a, 9 (2), pp. 306.
5. 1143-1153. Su Jingzhi, Wen Min, Ding Yihui, et al., Hiatus of global warming: A review [J]. Chinese Journal of Atmospheric Sciences (in Chinese), 2016, 40 (6), pp. 1143-1153, doi: https://doi.org/10.3878/j.iSSN. 1006-9895.1512.15242, 1144-1146.
6. 1143-1153. Su Jingzhi, Wen Min, Ding Yihui, et al. Hiatus of global warming: A review [J]. Chinese Journal of Atmospheric Sciences (in Chinese), 2016, 40 (6), pp. 1143-1153. DOI: 10.3878 / j.i SSN. 1006-9895.1512.15242, 1144-1146.
7. Leeson, D., Mac Dowell, N., Shah, N., Petit, C., Fennell, P.S., A Techno-economic analysis and systematic review of carbon capture and storage (CCS) applied to the iron and steel, cement, oil refining and pulp and paper industries, as well as other high purity sources. International Journal of Greenhouse Gas Control 61, 2017, pp. 71-84.
8. Seipp, C., Williams, N., Kidder, M., Custelcean, R., CO2 capture from ambient air by crystallization with a guanidine sorbent. Angew. Chem. Int. Ed. 2017, 56 (4), pp. 1042-1045.
9. Techno-economic assessment of CO2 direct air capture plants, Journal of Cleaner Production 224, 2019, pp. 960–962.
10. Su Jingzhi, Wen Min, Ding Yihui, et al., Hiatus of global warming: A review [J]. Chinese Journal of Atmospheric Sciences (in Chinese), 2016. 40 (6), pp. 1143-1153. DOI: https://doi.org/10.3878/j.iSSN. 1006-9895.1512.15242, 1144-1146