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P5_10 Can Vacuum's Save the World?

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Abstract

Global warming has been a major problem for humanity since the industrial revolution, carbon dioxide emissions are now sky high due to increased energy demands every year. Large efforts are now taking place to slow down our CO₂ emissions and postpone global warming. In this paper we show how Climeworks vacuum cleaners operate and calculate that a power supply of 1.74×10^{20} J/yr is required, to clean the global annual CO₂ emissions. This power supply is equivalent to 59.88 and 11.56 times larger than the USA's nuclear and total power output respectively in 2018.

Introduction and Theory

Climeworks vacuum cleaners are one of the newest solutions to battle climate change, utilising direct air capture (DAC) technology to filter and clean the air of CO₂. In 2018, the first ever commercial-scale direct air capture facility was built in Switzerland, and since then more facilities are now being built around the world, with Climeworks' goal to filter 1 % of global Carbon dioxide emissions in 2025. In this paper we explain the DAC technology, calculate the number of vacuums required to remove human emissions and the respective power requirement. Comparing these results to the USA's nuclear and total power output [1].

DAC is a process of capturing CO₂ directly from the ambient air and producing a concentrated stream of CO₂ for sequestration or commercial utilization [2]. Large vacuums are used to push this ambient air through a filter containing a liquid solvent (usually amine-based), to separate the CO₂ and produce Sodium carbonate. This carbonate is heated to produce a highly pure CO₂ stream, which can be stored in

basaltic rocks through mineralization in natural sinks. Figure 1 shows Climeworks' DAC method currently being used in their facilities [2].

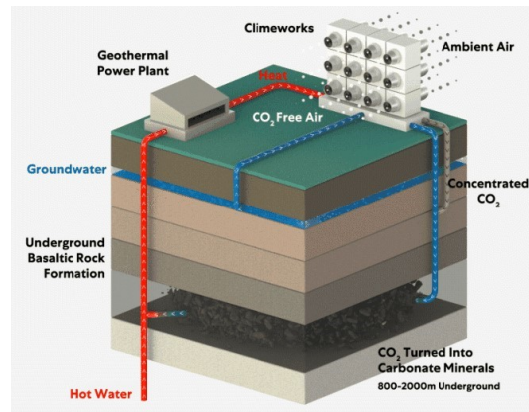


Figure 1: DAC method for Climeworks Switzerland's facility

One facility with 19 CO₂ vacuums can collect 900 tons annually, with 60 % of its energy usage coming from recycled heat [3]. If the other 40 % was powered by an renewable energy supply, then this is an emission free solution. The minimum amount of energy required to filter and

store the CO₂ is 12 *GJ* per tonne [3]. To halt human exacerbation of climate change, 100 % of annual carbon emissions would need to be filtered (completely cleaned up, CCU), but how much power would this need and is it possible? We compare the USA's nuclear and total power output to show the viability of this project.

Discussion

We assume that currently no human emissions are being removed from the atmosphere, requiring a clean up of 36.16 billion tonnes [4] of CO₂ annually. With each set of 19 vacuums being able to clean 900 tonnes annually, we will require 40.2 million sets of vacuums, a total 763.4 million vacuums for CCU. For CCU 4.23×10^{20} *J/yr* of energy would be required, therefore a total of 1.74×10^{20} *J/yr* must be produced from outside sources. The 2018 USA's nuclear power output was 807,084 *GWh* [1], using basic unit conversions this is equal to 2.9054×10^{18} *J/yr*, The 2018 USA's total power output was 4,178,000 *GWh* [1], which is equivalent to 1.504×10^{19} *J/yr*. Therefore, to power these Climework vacuums, it would require 59.88 times the USA's nuclear power output and 11.56 times the USA's total power output. This is a colossus amount of energy which is currently implausible to produce by USA alone. The energy would also have to be produce near basaltic regions for easy storage of the CO₂, increasing the difficulty even further.

The current cost for the this process is around \$200 per tonne of CO₂, with future R & D looking to quarter this cost to \$50 per tonne [3]. Therefore the total cost of this project would be \$7.232 trillion. With the current estimated reduction in overall cost, this would be reduced by 75% to \$1.808 trillion in a few decades. If the expected cost is related to the USA's CO₂ emissions [4], then they would need \$1.2 trillion to clean all their emissions, this is only 1.6 times their current army budget!

Conclusion

We have analysed the energy and cost requirements to use Climeworks DAC technology as

a means to remove all human CO₂ emissions from the atmosphere. We assumed the vacuums ran at 90% efficiency, with 40% energy requirement from nuclear power, to predict the energy costs for CCU. We calculated that 763.4 million CO₂ vacuums have an energy requirement of 1.74×10^{20} *J/yr*, for CCU. We conclude that to meet this energy requirement, the project would need 56.88 times the USA's nuclear power production. For optimal efficiency this power should be produced near basaltic regions to meet the Climework Vacuums requirements. We calculated that to collect and store this amount of CO₂, it would cost roughly \$7.232 trillion dollars but this price is expected to be reduced by 75% in the next few decades. Currently this is not a plausible solution for climate change unless costs and energy requirements are reduced.

We recognise that these processes are currently still in development and have been dramatically up-scaled for the purpose of this paper. Thus, the conclusions drawn from this paper are estimates and suggestions at most, for an ambitious solution for climate change. To further this study, ideas that reduce the cost of Clime-work vacuums could be studied in further detail, to test the viability when applied globally and not just to the US.

References

- [1] <https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php>, Electricity explained [Accessed 10th December 2020]
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