Science AMA Series: We are researchers from the University of South Africa and we're putting greenhouse gases directly into actual greenhouses; we thereby capture carbon emissions, reduce water consumption and increase crop yield. Ask Us Anything!

GasesforGreenhouses [1] and r/Science AMAs[1]

[1]Affiliation not available

April 17, 2023

Abstract

Water scarcity poses a severe threat to all humankind, with rapidly growing demand pressuring already-constrained water resources, many of which are unsustainable. Figuring out where our water ends up is therefore a crucial step toward finding ways to use it more efficiently and try to ensure that we, as a species, are still around a few generations from now. Dr Neil Stacey is a young researcher previously known for best known for patented advances in bio-fuels production technology. In late 2016 he set out to use chemical engineering modeling methods to examine water usage in agriculture, which comprises 70% of all of mankind's water consumption. Professor Diane Hildebrandt lent her considerable support to the project soon after. She is a director of UNISA's IDEAS institute. She has been the recipient of a number of prestigious scientific awards including the Meiring Naude Medal, the Bill Neale-May Gold Medal, the Distinguished Woman Scientist Award and an AfricanUnion Scientific Award. She has been the author or co-author of over one hundred and fifty peer-reviewed scientific publications including three textbooks and an invited paper in Science. By building chemical and thermal models of greenhouses as bio-reactors, we have been able to develop fundamental insights into cause-and-effect relationships in greenhouse design and operation. We found that greenhouse operation is constrained by the necessity of supplying adequate CO2 for photosynthesis. Since CO2 is highly dilute, this constraint demands a very high air-flow through a greenhouse which in turn causes excessive water evaporation and heat losses. Consequently, providing enriched CO2 can drastically reduce the heat and water requirements of a greenhouse. In a paper currently in the final stages of review, we showed that using membrane separation to partially enrich air as a feed can cut water usage considerably. We also investigated the possibility of using power station flue gas as a source of enriched CO2. In a recent paper, we quantified the potential costs and benefits of diverting flue gases from gas-fired power stations into greenhouses, finding that this approach can achieve large-scale carbon capture without costly separation, while massively boosting agricultural output and drastically reducing water requirements. And so, we are here to field your questions as we advocate for putting greenhouse gases into actual greenhouses. We'll be back at 12 pm ET to answer your questions, Ask Us Anything! Edit: Diane is awaiting a plane to Johannesburg, while Neil is out for a drink at South-West London's best bar, Dutch Courage, so there will be a bit of a go-slow here until Neil is back home, around 2pm ET.

the WINNOWER

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GASESFORGREENHOUSES R/SCIENCE

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CORRESPONDENCE:

DATE RECEIVED:
January 09, 2018

Would like to thank you for doing this.. What kind of plants are you using? Are there any plants that are especially efficient at this?

DarwinApprentice

There are a few considerations involved but the one we have focused on is that different plant species

DOI:
10.15200/winn.151541.15875

ARCHIVED:
January 08, 2018

CITATION:
GasesforGreenhouses , r/Science , Science AMA Series: We are researchers from the University of South Africa and we're putting greenhouse gases directly into actual greenhouses; we thereby capture carbon emissions, reduce water consumption and increase crop yield. Ask Us Anything!, *The Winnower* 5:e151541.15875 , 2018 , DOI: 10.15200/winn.151541.15875

respond differently to elevated CO2 levels, depending on the particular chemical pathway for photosynthesis that they use. C3-type plants respond most favourably. That category includes the majority of fruits and leafy vegetables, which conveniently happen to be the most popular crops to grow in greenhouses anyway. They also tend to be more nutritious and healthy than the C4-type grain crops that predominate the agricultural sector, so we are hoping that a side-effect of this technology will be to improve diets.

Extremely interesting topic.

To give us noobs an idea of the scale of the problem, let's say we want to capture the CO2 of a natural gas power plant (let's suppose a 500 electric MW one). How much land surface should we devote to greenhouses to capture most part of the output? If we feed directly the flue to the plants, what can we get? Just wood that we would then store somewhere to achieve carbon storage, or could we even feed the flue to some "good" crops (food plants, feed for livestock etc...). I'm thinking about pollution problems from other components of the flue gases on top of CO2

lucaxx85

There is tremendous variation involved in yield per square meter, depending on factors like crop species, light levels, fertilizer effectiveness and others. However, we have done initial scoping around a fairly standard average crop yield for cabbages and arrived at a figure of around 3 hectares per 1MW of power production capacity, growing something like 20 tons per day of plant matter.

Which is pretty freaking enormous. If we were to capture all the flue gases just from gas-fired power stations with this method, the resulting food production would be on the order of millions of tons per day, which is enough to outstrip all unmet food demand.

So we tend to view this approach as primarily a means of saving water and secondarily a means of boosting agricultural output, with carbon fixation as a bonus. One possibility which would change that equation would be using these greenhouses primarily as nurseries, growing sapling trees past the point where they need loads of water and then planting them elsewhere. I personally (Neil) harbour a pet image of rolling nurseries on wheels, growing a grove of saplings from seed at an accelerated pace and then rolling along to start again further along.

As to your second question; as long as the flue gas doesn't have anything nasty, then there's no issue with using it with food crops. Natural gas tends to burn very cleanly so that is where we've focused.

Hi there! I'm wondering about your membrane technique. Is it an active system (where you need to pump air through it) or just a passive filter? Can you run down for us how a typical setup would work/how much it would cost?

lucaxx85

It has to be an active system, with a decent pressure difference, in order to achieve a good enough separation. If the degree of separation is small then you still need huge volumes of air, except that now you have to get those volumes through a membrane on the way.

The most obvious approach is to have an inorganic silica membrane exposed to open air on the retentate side, with the permeate side pulled through a vacuum pump before being discharged into the greenhouse.

One of our collaborators, professor Maria Fernandez of the University of Alicante, has joined us to examine different configurations including recycle streams and water recovery through condensation,

so it's very much still up in the air regarding the specifics of a setup.

A standard rule of thumb for membrane separation is that your compressor is half your capital cost and 90% of your operating cost, so once you've figured your flow rate you can estimate your costs pretty effectively using benchmark costings for compressors.

Pineapple on pizza or no?

drchopsalot

That's a bit too serious a question for this forum, isn't it? (but yes)