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Carbon Dioxide Enrichment for Greenhouses in a Decarbonised Future

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Background

To reduce CO_2 emissions, great efforts are being made to phase out fossil fuels in favour of carbon-neutral alternatives. For greenhouse horticulture, which currently uses natural gas as an energy source, electrified and 'fossil free' greenhouses are also expected to be the way forward. Currently, extra CO_2 is introduced into greenhouses to increase yields considerably. **In a decarbonised future, where will greenhouses get this supplemental CO_2 from?**

Approach

The objective of this project is to investigate fossil-free CO_2 sources for the Dutch greenhouse horticulture sector and how they can be safely and effectively delivered to the crop. We look at both mainstream and experimental alternatives using literature and simple calculations. Our findings and their implications are reported in a **white paper**, which aims to provide ideas for future research to investigate specific solutions in more detail.

Outline

This project looked at CO_2 supply from four perspectives:

1. **Quantity**: how much CO_2 does the sector need and how much is available?
2. Quality in terms of **concentration**: what is required and how can the desired concentration be achieved?
3. Quality in terms of **purity**: which contaminants are likely, harmful, and how can they be removed?
4. **Distribution** to the greenhouse

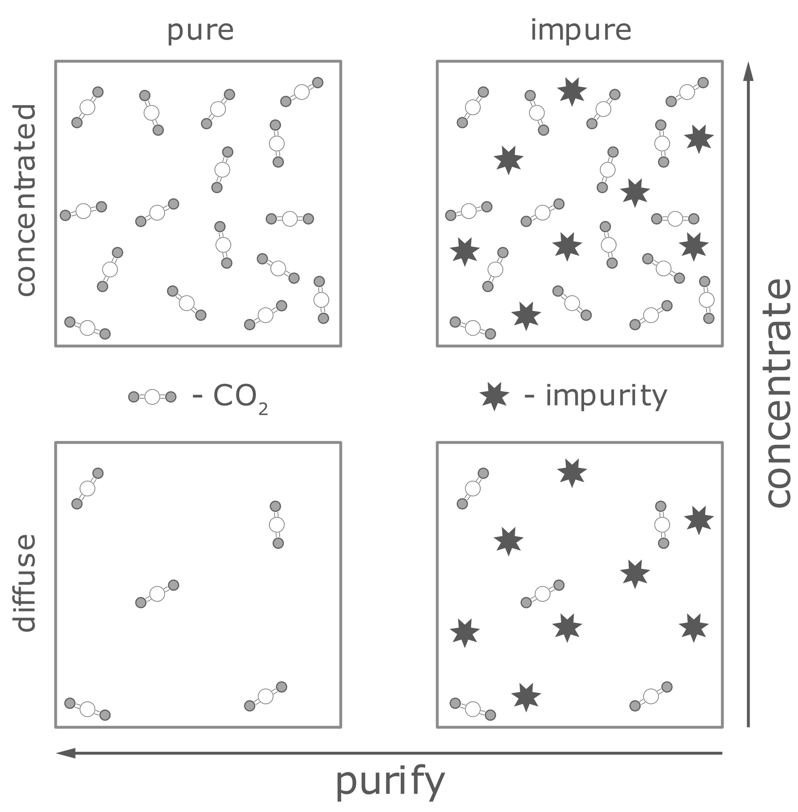

Figure 1: The difference between concentration and purity of CO_2-containing flows

Results (1)

Quantity Ignoring direct air capture (DAC), we expect enough non-fossil CO_2 from other sources to be available to meet the sector's projected demand of 1.8-3.0 Mt in 2030. This has the advantage of already being concentrated compared to ambient concentrations (see Figure 3). By 2030, biogas upgrading and ethanol fermentation alone are projected to produce enough CO_2 for the entire sector.

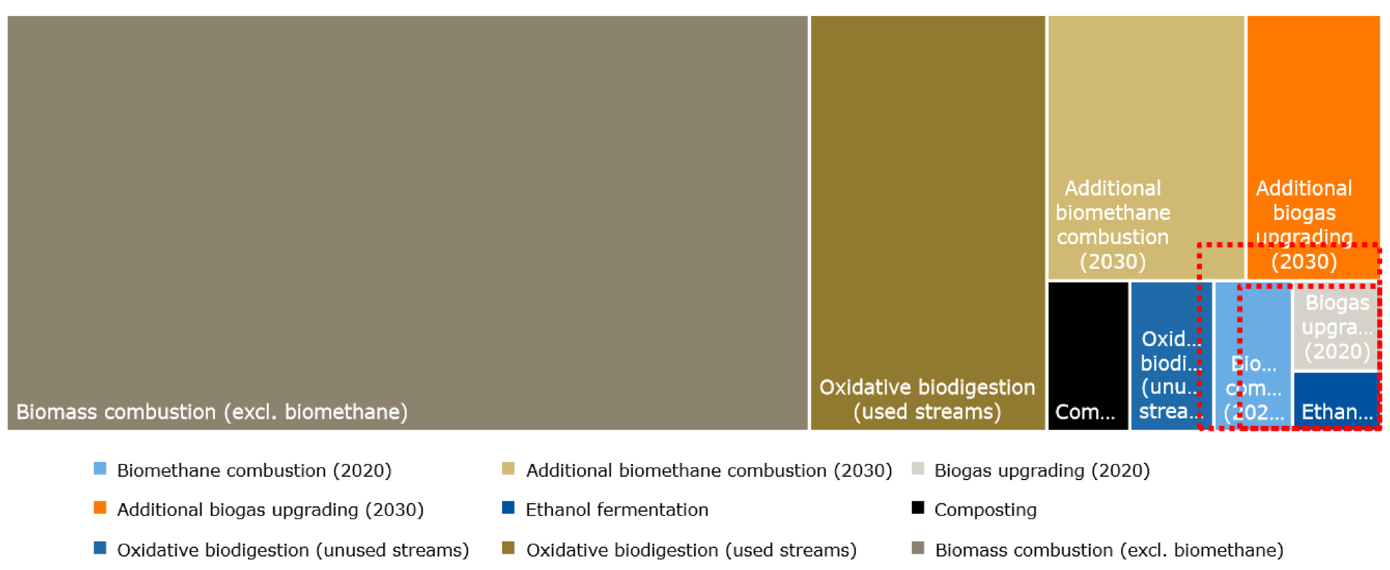

Figure 2: Quantities of CO_2 sources (current and future), with the range of expected demand in 2030 in red.

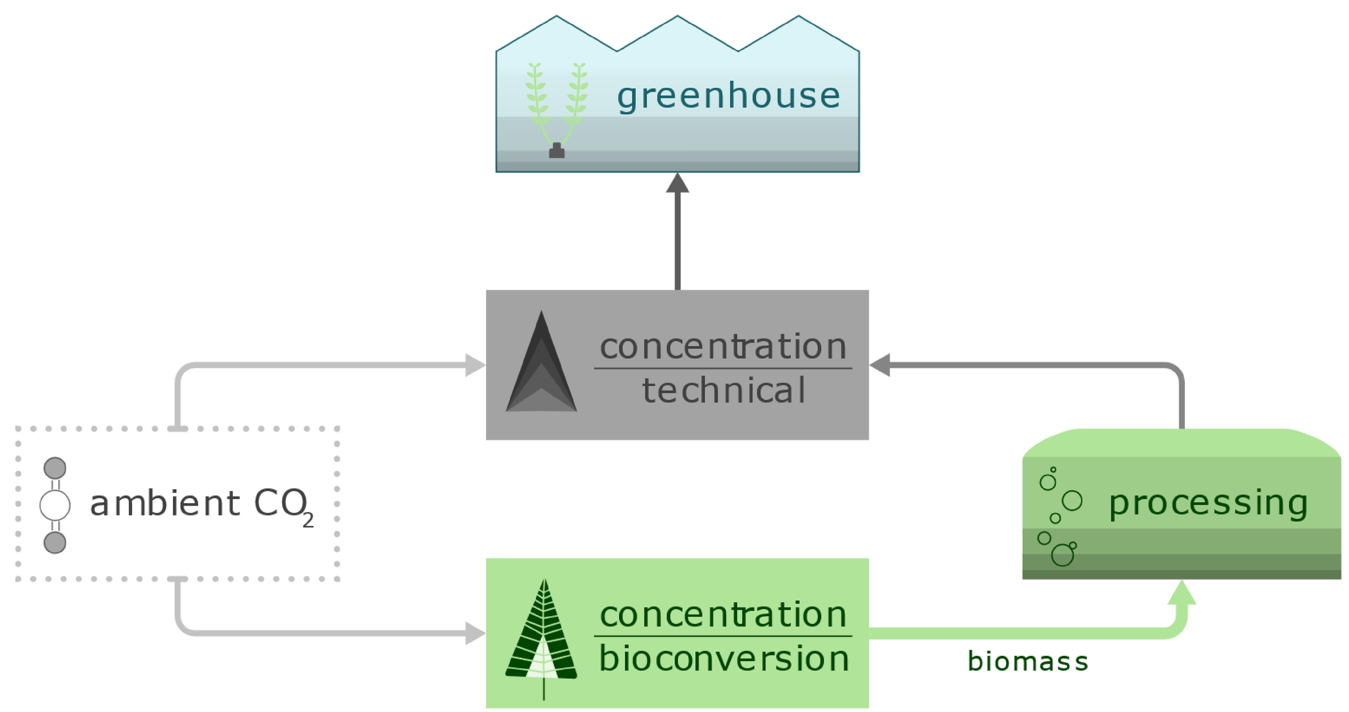

Figure 3: A conceptual diagram of the difference between biogenic and ambient CO_2 for supply to greenhouse horticulture. Biogenic CO_2 is ambient CO_2 after an extra concentration step.

Results (2)

Concentration In theory, just 4% CO_2 is enough, with typical ventilation rates – but such low concentrations require larger volumes making them impractical. Even on-site low-concentration DAC has been found to be less practical than concentrating to 100%. Biogas upgrading and ethanol fermentation produce the most concentrated CO_2 flow. Various concentration technologies are discussed for the other sources.

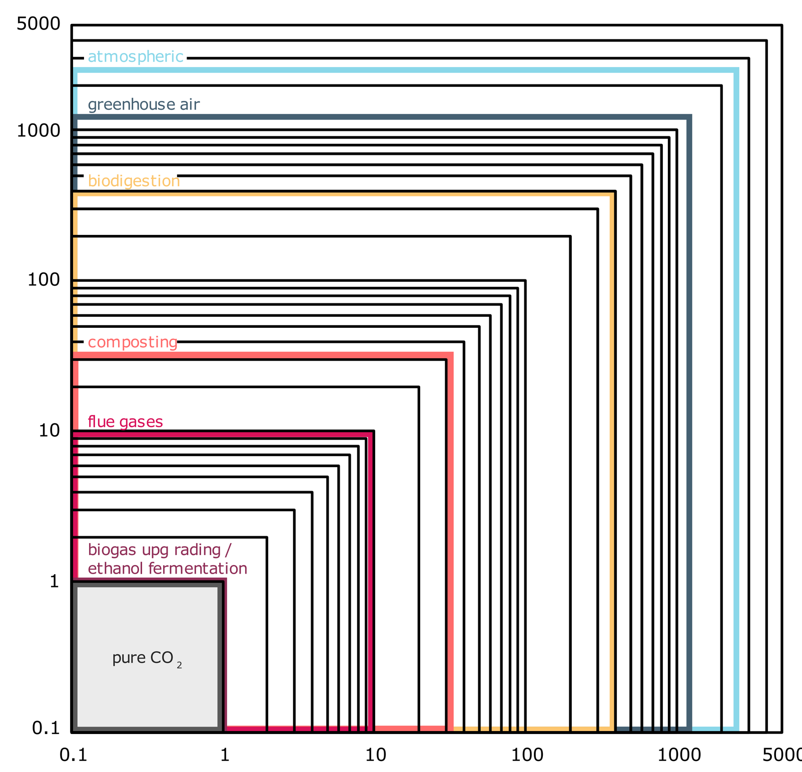

Figure 4: The volume (represented as area) to carry a unit of CO_2 under various concentrations

Purity CO_2 from composting and biomethane combustion is likely to contain harmful contaminants, however no more than from burning natural gas, for which growers have the capacity to remove contaminants. Biomass combustion produces the most contaminants. The white paper outlines the advantages and disadvantages of various purification technologies for NO_x, SO_2 and ethylene.

Distribution A number of mainstream solutions are discussed, as well as the advantages and methods for CO_2 buffering.

Conclusions

- There is expected to be enough biogenic CO_2 to meet Dutch greenhouse horticulture's projected demand in 2030.
- CO_2 from ethanol fermentation and biogas upgrading are the purest and most concentrated sources of biogenic CO_2. For other sources, we discuss purification and concentration techniques.
- Supply options are unlikely to be different to those used today. Fuel cells have the disadvantage of coupling CO_2- and energy release. Buffering has an important role to play in stabilising supply.

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