

# Greenhouse CO<sub>2</sub> dosing for enhanced crop growth

CO<sub>2</sub> Summit, Innsbruck, March 2019

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## Thesis...

CO<sub>2</sub> – compliments  
other “green”  
greenhouse  
technologies

# The perfect greenhouse growing environment

- Water and nutrients
- Soil or growth substrate
- Good air circulation
- Good light, but not at night
- Warm, but not too hot
- Humid, but not too moist
- Plenty of CO<sub>2</sub> in the air, but not too much



# Greenhouse CO<sub>2</sub> sources

- Combustion of cylinder propane or LPG
- Combustion of piped natural gas or LNG
- Natural gas fired CHP exhaust gas
- Direct CO<sub>2</sub> injection
  - Pipeline supply (NL special case)
  - Bulk liquid storage & vaporisation (standard for commercial growers)
  - Cylinder supply (small scale growers and hobby gardeners)





## Combustion vs CO<sub>2</sub> injection - heat

- Combustion of LPG or natural gas yields humidity, CO<sub>2</sub> and heat
  - Win-win for the greenhouse?
- Simple, low cost solution but inflexible – no independent control of heat and CO<sub>2</sub> input
- Ideal for cold climates, eg Canada
- CHP for very large facilities, eg NL



# BOC Australia differentiated CO<sub>2</sub> grades:

1. Beverage grade: CO<sub>2</sub> is an ingredient and is physically ingested
2. Food grade: CO<sub>2</sub> is in contact with the food that will be eaten, eg MAP
3. Environmental grade: CO<sub>2</sub> is introduced into the greenhouse growing environment where it will come in contact with the food in a diluted form and the food generally undergoes further processing / packaging before being consumed
4. Industrial grade





# Typical case study: “Murphy Fresh”, Australia

- Tomato crop
- 2.6 ha under glass
- 1500ppm CO<sub>2</sub> control point
- 1.2 to 1.8 Te CO<sub>2</sub> per day per ha
- BOC supplies “Environmental Grade” bulk liquid CO<sub>2</sub>
- 30 Tonne tank, filled circa 2x per week



## Beyond plant crops

- CO<sub>2</sub> is used for algae growth
- Algae is harvested for nutrition and healthcare products
- The liquor residue (after algae harvesting) can be used as a hydroponic greenhouse nutrient & water source





# Growth drivers for CO<sub>2</sub> usage vs combustion

- CO<sub>2</sub> offers better process control and increased flexibility
- Desert greenhouses in the middle east and Australia are a growth phenomenon and require CO<sub>2</sub>, but not so much heat
- Geothermal energy in Europe is providing the required heat without CO<sub>2</sub> as a combustion by product
- CCU in the Netherlands (from pipeline supply of refinery SynGas and bioethanol by-product CO<sub>2</sub>) is making CHP systems redundant



## “Vertical farming” in the middle east

- Hydroponic growing can reduce water consumption by up to 95%
- Local growing reduces aviation transport environmental impact
- One grower: 70+ Ha under glass across 9 farms
- CO<sub>2</sub> from direct combustion would generate too much heat
- Up to 1kg CO<sub>2</sub> per 1kg tomato crop reported
- Example supplier: food-grade bulk liquid CO<sub>2</sub> from Gulf Cryo
  - Traceable product batches
  - CO<sub>2</sub> is a by-product of ammonia or ethylene glycol production





# Seawater farming in the desert

- Sea-water desalinated with PV solar powered RO membrane desalination plant
- Evaporative cooling of pumped seawater reduces / eliminates chiller power requirements
- CO<sub>2</sub> from a direct combustion source would generate too much heat and be counter-productive





## Concentrated solar power (CSP) to steam in Southern Australia

- Sundrop Farms, Adelaide
- 20 ha farm, tomato crop
- Mirrors reflect sunlight to the 126m high solar tower (Aalborg CSP)
- Energy is used for water desalination, heat and electrical power generation (via a steam turbine)
- CO<sub>2</sub> from direct combustion would create additional heat and be counter productive
- Air Liquide bulk liquid CO<sub>2</sub> supply



A Sundrop greenhouse turns seawater and sunlight into energy and water. We then use sustainably sourced carbon dioxide and nutrients to maximise the growth of our crops.

# Geothermal growing in Bavaria

- Gemüsebau Steiner GmbH & Co KG
- Circa 20 ha under glass
- Tomato, capsicum & cucumber
- Heat from geothermal energy – temperature / pressure profile ideal for warmth, not sufficient for electrical power
- Linde bulk liquid CO<sub>2</sub> supply
- Industrial grade CO<sub>2</sub>
- 0.4 to 0.8 kg CO<sub>2</sub> per kg tomato crop





# Carbon capture and re-use in NL

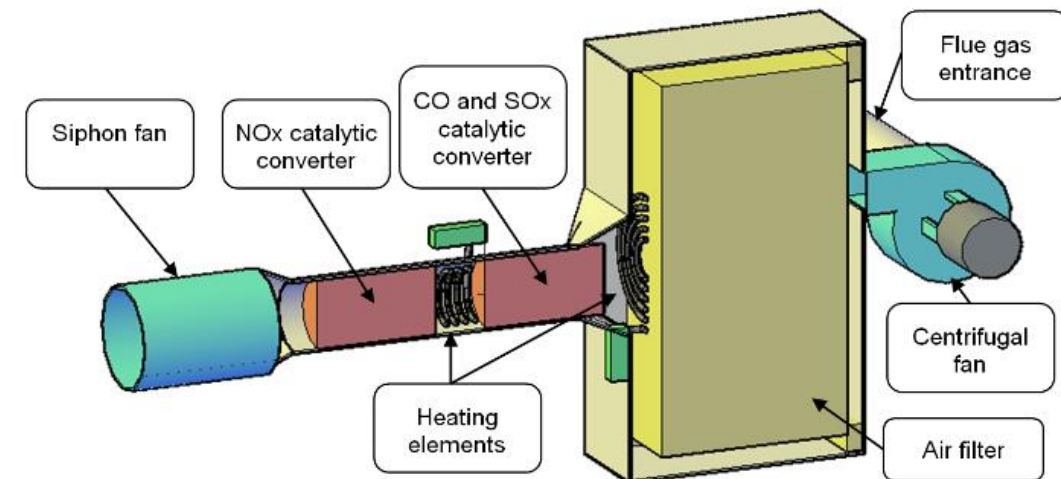
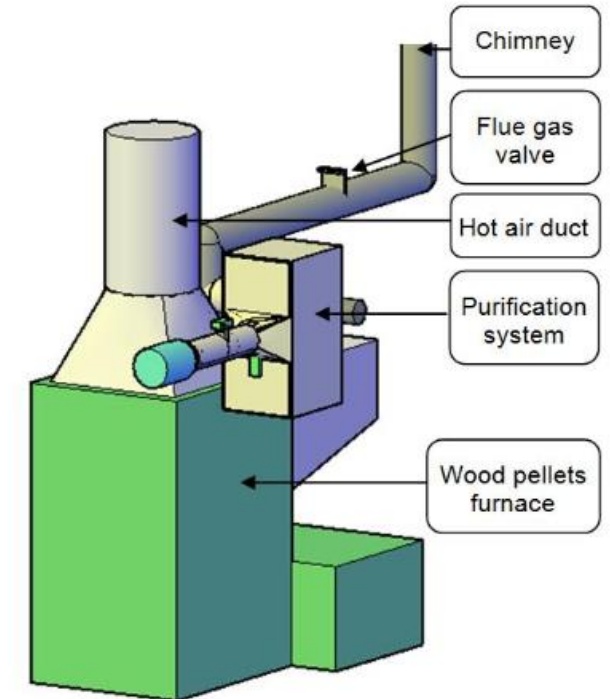
- OCAP pipeline delivers 400,000 TPA of CO<sub>2</sub> to 500 greenhouses with 2,000 ha under glass
- CO<sub>2</sub> from the Shell Pernis refinery (SynGas) and Abengoa bioethanol plant
- CHP is the other main CO<sub>2</sub> source for the NL greenhouse industry, but pressure to reduce carbon footprint
- CO<sub>2</sub> storage in the dis-used Q16-Maas natural gas field is proposed to smooth out the annual peak in demand (summer high, winter low) and thereby increase pipeline capacity to support growth in demand





# Combustion goes green... with biomass

- Heat and CO<sub>2</sub>, or CHP and CO<sub>2</sub> from wood chip
- Carbon-neutral fuel
- Requires flue gas clean up to avoid build up of CO, SO<sub>2</sub> & NO<sub>x</sub>
- Emerging solution in cooler northern climates with abundant forests, eg Canada



## Conclusion - growth

- Demand for CO<sub>2</sub> in greenhouses is growing in many locations...
  - Geographic expansion to hot climates
  - New crops, eg algae
- CO<sub>2</sub> injection de-couples CO<sub>2</sub> & heat input to compliment green technologies, eg geothermal
- Combustion-generated CO<sub>2</sub> is likely to remain popular in cooler climates with abundant energy resources, eg Canada



# Conclusion – commercial impact

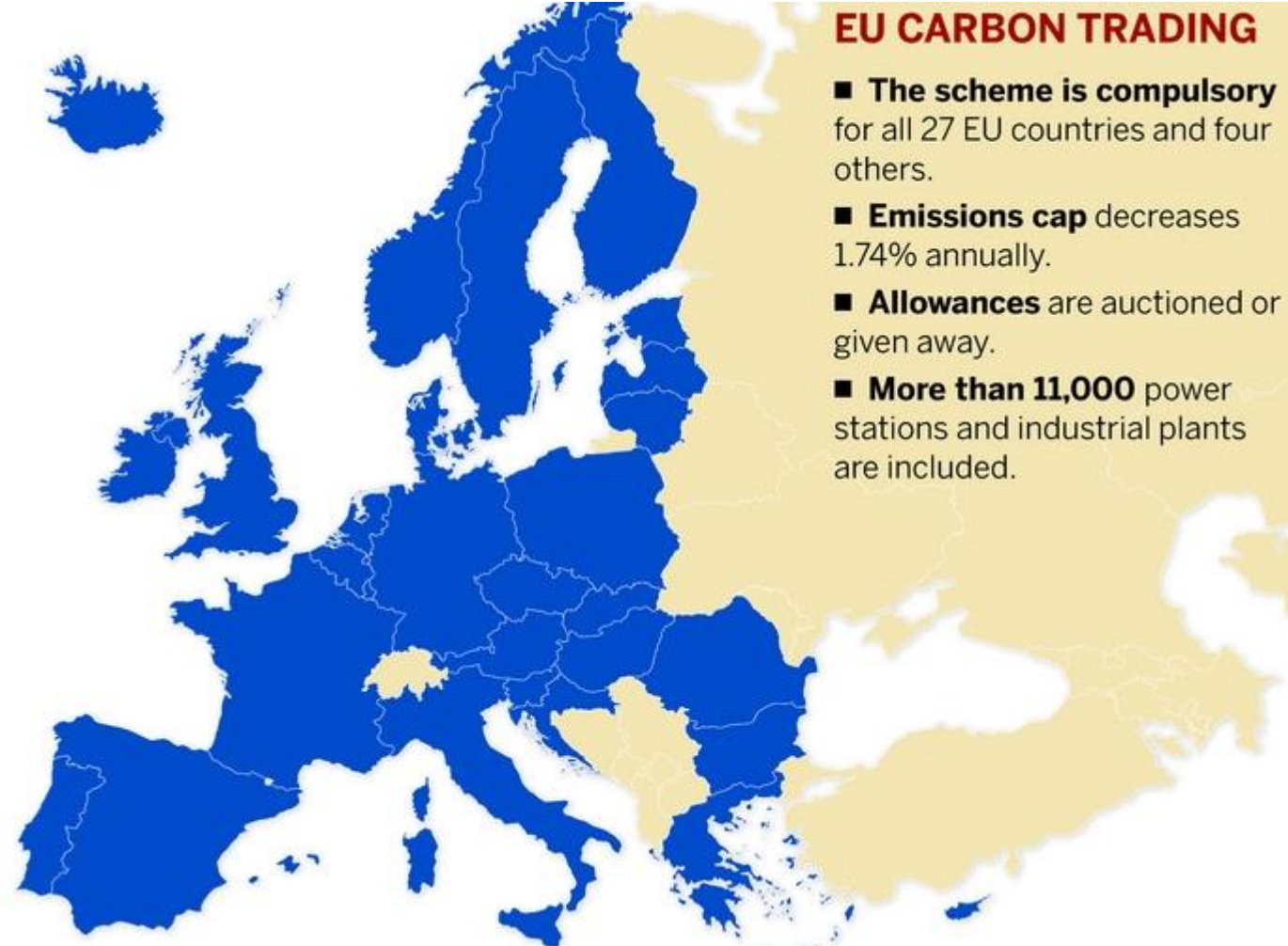
- Opportunities for the broad industrial gases industry...
  - Propane / LPG
  - CO<sub>2</sub> in various supply modes
  - Pipeline infrastructure
  - Cylinders, tanks etc
  - Gas control equipment
  - Gas sensor calibration gases





## Conclusion – environmental impact

- Likely to be viewed as positive
  - CO<sub>2</sub> Carbon capture and re-use
- Potentially viewed as carbon neutral
  - Biomass combustion for heat & CO<sub>2</sub>
  - Biomass fired CHP for heat with exhaust gas for CO<sub>2</sub> dosing
- Likely to be viewed as negative
  - LPG/Natural gas combustion for CHP or heat and CO<sub>2</sub> production



## Acknowledgements – images and case studies

- BOC – Chris Dolman, John Roynon
- Coregas - Alan Watkins, TJ Croeser
- Gulf Cryo - Mike Huggon, Sami Huneidi
- Gemüsebau Steiner – Wolfgang Steiner

***„Alle sagten: Das geht nicht. Dann kam einer, der wusste das nicht und hat's gemacht.“***



# Thank you. Questions?

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