Carbon dioxide dosing, water desalination and carbon capture for greenhouses

By Stephen B. Harrison
Principal, Germany

Green agro-tech for green produce – solar power, biomass combustion, water desalination and CCR for commercial greenhouses

Crop science and agro-tech are hot discussion points in the German and global chemicals press today. We often read about the transformations inside Bayer, as it shifts its focus towards these product groups through its recent Covestro Materials Science division spin-off, which now encapsulates its former specialty chemicals and polymers businesses. BASF is also catching up in this agro-tech market, which its recent business acquisitions from Bayer that see it enter the seeds, non-selective herbicides and nematicide seed treatments product groups to complement its established position in crop protection products and digital farming.

The agro-tech topic is of great interest the broader energy and chemicals space, where Nexant is a leading global advisory firm, with ammonia and fertilizer production being intrinsically linked to natural gas sourcing and other crop growth enhancers, such as CO_2, being produced as by-products from refineries and bio renewables. Market studies, such as the “Biorenewables Insights – Ethanol as a platform Chemical” published in October 2018, are of interest to this sector from two directions: ethanol fermentation relies on crops grown using modern agro-tech and it is also a natural and renewable source of CO_2 for eco-sensitive food production applications.

Additionally, the Nexant “Market Insights: Specialty Fertilizers – 2018”. It provides a comprehensive review of global Specialty Fertilizers market and includes discussion regarding key market drivers and constraints, including: regulatory, environmental, consumer and technology trends across nine global regions from North America through EMEA to Asia Pacific, and China.

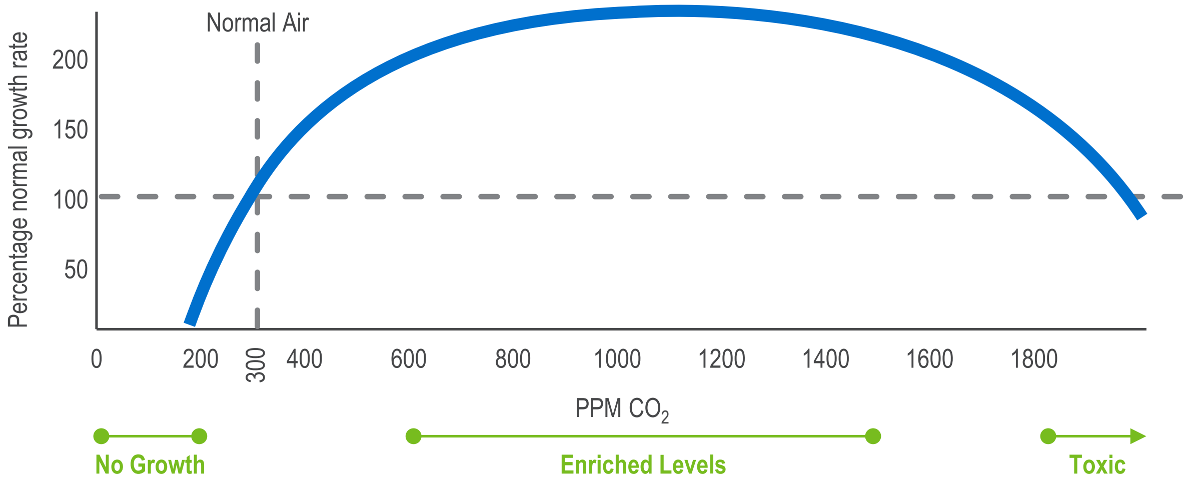
Finding the sweet-spot for growing conditions

Crops such as tomatoes, cucumbers, capsicum peppers and lettuce are regularly grown in modern commercial greenhouses. Light, water, temperature, nutrient supply and carbon dioxide (CO_2) levels are controlled to create a growing environment that optimises crop yields. For traditional greenhouse crop producing and exporting countries, such as the Canada, the Netherlands and New Zealand, investment in high-yield growing processes using a mix of technologies has been intense in recent decades.

Perhaps surprisingly, some crop exports from the established green-house crop production countries have recently been in decline. Why? In large part due to investment in smart vertical farming techniques in hot and arid countries, such as Australia and Saudi Arabia. This development has been enabled by modern technology, such as PV solar power generation, concentrated solar power (CSP) and reverse-osmosis (RO) sea water desalination. The result has been an increased level of self-sufficiency that has reduced these countries dependence on imported crops.

The emerging greenhouse-growing nations are not alone in implementing green technologies to raise their crops. Carbon capture and re-use, biomass combustion and geothermal energy are breaking into the mature greenhouse crop production markets to enable their evolution as a new economic and environmental landscape is being shaped.

The beneficial influence of CO_2 on photosynthesis

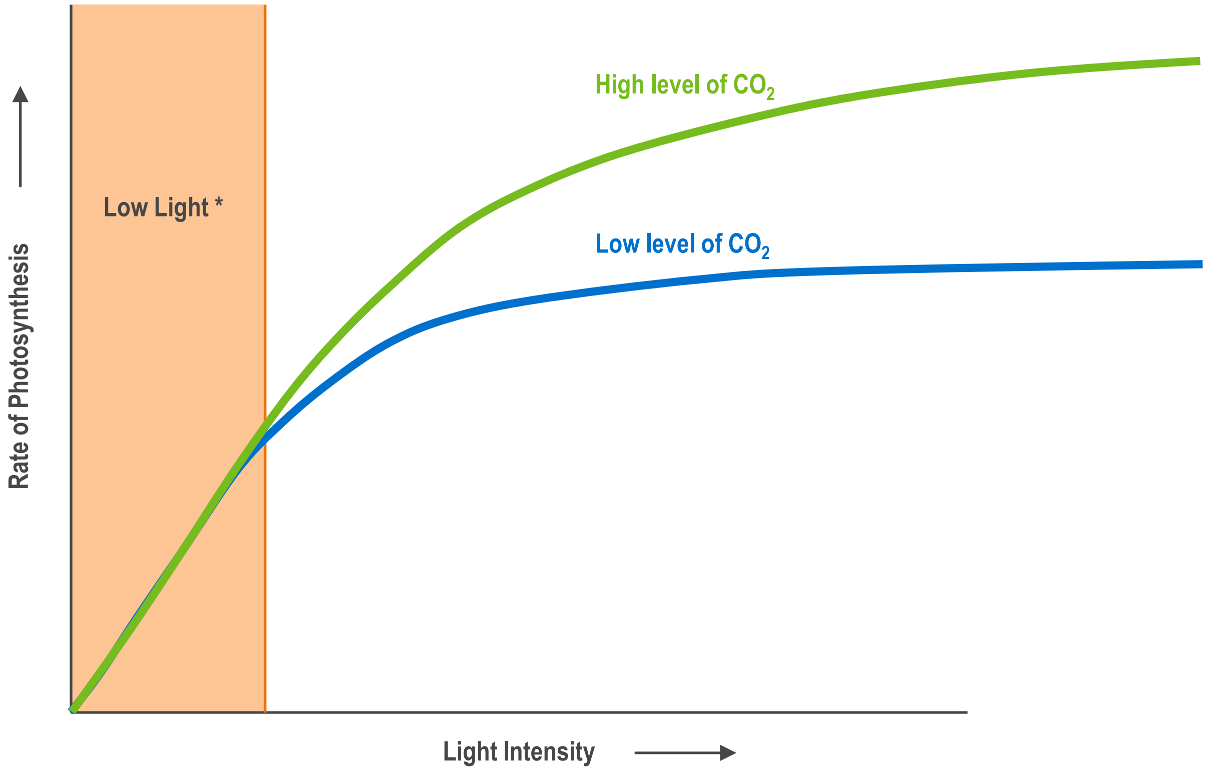


Elevated levels of CO_2 during daylight growing hours enhance photosynthesis and plant growth. In greenhouses, the growth rate of plants can be improved during growing hours almost in direct proportion to the increase in CO_2 concentrations in the air, up to approximately 800 ppm. This is about twice as much as the natural concentration of CO_2 in natural ambient air. Higher CO_2 concentrations also increase growth rates, but each incremental increase in CO_2 levels above about 800 ppm has diminishing benefit to the plants. Despite these diminishing returns, many commercial greenhouse operators control the CO_2 levels at between 1000 and 1200 ppm to fully exploit the potential of CO_2 addition.

To measure and control the CO_2 level in the greenhouse, a non-dispersive infra-red (NDIR) gas sensor is typically used. The target set point will generally be around 1200 ppm of CO_2. When the sensor detects a reduced CO_2 level in the greenhouse it will activate the CO_2 dosing system. Then, when the required CO_2 level has been achieved, the measured value will increase, and the control system will shut off the CO_2 supply.

Optimised CO_2 levels in greenhouses raise productivity and crop yields considerably. When the CO_2 level in the greenhouse is optimised, the plants will produce uniform fruit, salads and vegetables of the best quality. So, CO_2 injection can maximise the yield, crop quality and the sales price for the harvest.

Harvesting the sun's energy for electrical power and water

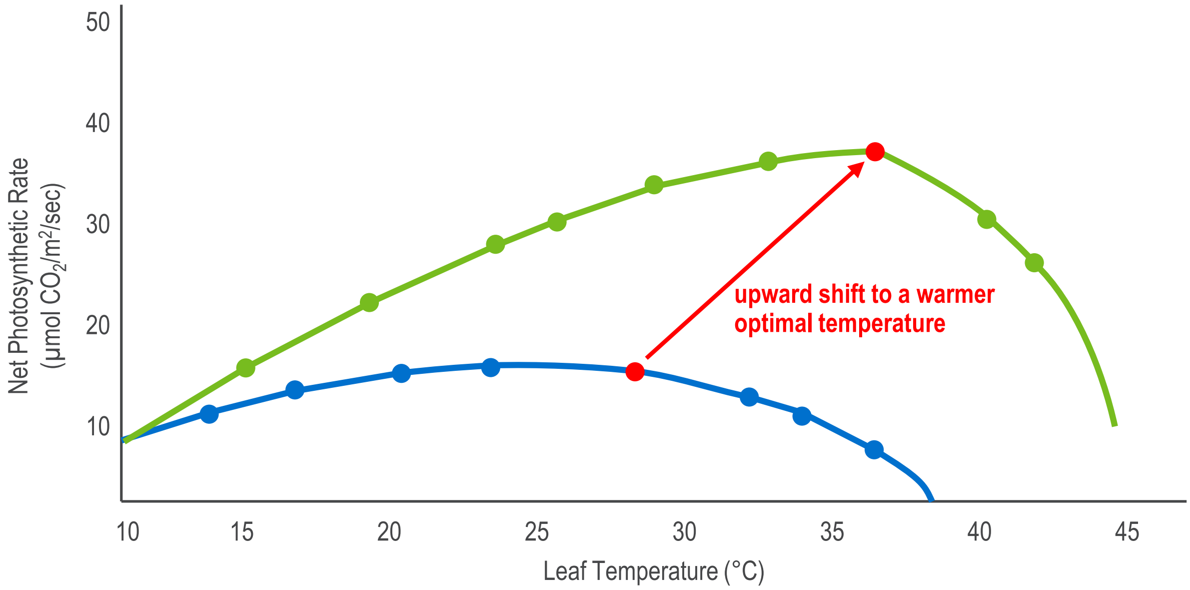


* Shade, cloudy day, early morning, evening

Light is also essential for photosynthesis and plant growth. And, its importance in greenhouse farming stretches beyond that. The most modern farms, which are being built in hot, sunny arid countries, are also reliant on the sun's energy for their general operation. For example, on many farms in the Middle East and north Africa photo-voltaic (PV) solar panels are used to produce electrical power that is required for various services to the greenhouse, such as chillers for temperature control and pumps to operate reverse-osmosis (RO) membrane desalination plants. This RO technology tends to be the most cost-effective way to produce irrigation water for the farm.

In Australia, the tomato grower Sundrop has installed a 127m high concentrated solar power CSP) tower. This is used for sea water desalination for irrigation and to generate steam for heat and the production of electrical power in a turbine. This cutting-edge technology, developed by the Danish company Aalborg, uses a computer-controlled array of mirrors to reflect sunlight to the top of the CSP tower where the intense heat is used to boil water.

Temperature control – heating and cooling



Temperature also has a strong influence on photosynthesis and optimal growing conditions. At ambient CO_2 concentrations, the optimum temperature for crop growth is around 25 °C. At the elevated CO_2 levels used in commercial greenhouses, the optimum increases to around 37 °C. However, in both cases, temperatures above the optimum quickly result in a decline in crop growth rates.

So, in cooler countries, such as Canada, the thermal management issue is clearly dominated by the challenge of heating. On the other hand, in the Saudi Arabia, where the average summer daytime temperature is 45 °C, thermal management during the daytime is all about chilling. Cooling these greenhouses is generally achieved either by electrically powered refrigeration plants or by evaporative cooling of sea water if the farm is located close to the sea. Evaporative cooling requires electrical power to pump the water, but the power consumption is significantly less than would be required to operate a refrigeration plant and this evaporative technique therefore enables the use of a locally generated PV power source.

Geothermal energy for greenhouse heating is the latest green technology to be used in this sector. In Germany, which ranks third in global food exporting countries, just behind the Netherlands, geothermal energy generated by the Kirchweidach project in the southern part of the country is being used to provide heat for the 20-hectare greenhouse farm operated by Josef Steiner. Similar projects are under consideration in the Netherlands. Geothermal heat is ideal for greenhouse use because the temperature of the water coming to the earth's surface is warm enough for heating purposes but is rarely high enough for electrical power production.

CO_2 addition methods

Dosing of carbon dioxide to the greenhouse can be from a CO_2 generator or direct injection from a pure CO_2 supply. Greenhouse CO_2 generators are often simple natural gas or LPG (often mostly propane) burners, which produce CO_2 and heat from combustion of the fuel gas. In larger greenhouse complexes, combined heat and power plants (CHP) are used to produce CO_2 and heat for the greenhouse and electrical power for the local grid. Combustion of biomass, generally wood, is also an emerging technique for CO_2 production and is convenient for greenhouse agriculture in locations such as Canada, where there are abundant local wood supplies.

In some of the cooler greenhouse growing countries, such as Canada or the Netherlands, it is important to heat the greenhouse to create optimal growing conditions. In emerging vertical farming nations, such as Saudi Arabia on the other hand, for much of the time 'thermal management' means avoiding high temperatures during peak daytime sunlight hours. This climatic difference has an influence on the preferred CO_2 source. The combustion of LPG to create both heat and CO_2 in New Zealand might be an attractive combination. However, in neighbouring Australia, the heat generated by the combustion might be a negative input to the greenhouse environment.

Given the above scenarios, it is clear that enhanced flexibility and improved dosing control can be achieved by using direct injection of CO_2 gas because it de-couples the production of heat from the injection of CO_2. The pure CO_2 supply for direct injection is typically from high pressure gas cylinders or vapourisation of liquid CO_2 from a large storage tank.

A notable exception to the supply of pure CO_2 for greenhouse injection is in the Netherlands. Ranking second in the world for food exports, after the USA, greenhouse crop production in the Netherlands, which is a very small country, is extremely intensive. This combination of high demand in a compact location has led to the development of a pipeline supply of CO_2 from two major sources to the multitude of greenhouses that are located between Rotterdam and Amsterdam.

The Shell Pernis refinery, in the port of Rotterdam, is a major feed to this pipeline. The CO_2 is a by-product of a steam methane reformer (SMR) that is used for SynGas production. A bioethanol plant, operated by Abengoa nearby, is the other major source. CO_2 is a by-product of the fermentation process that is integral to the ethanol production. This carbon capture and re-use (CCR) application is helping the local economy achieve environmental targets for CO_2 emissions reductions. Furthermore, under the EU Emissions Trading Scheme there are significant cash benefits to be achieved through effective carbon management.

In addition to the pipeline supply, there was a proposal made in 2017 to store CO_2 gas in the disused Q16 Maas natural gas field, which lies directly off-shore from the pipeline in Rotterdam. This buffer storage could be charged up during the winter months, where CO_2 demand in the greenhouses is low, and would then allow a higher CO_2 offtake from the pipeline in summer months, when the gas supply demand peaks to levels that are approximately twice as high as the winter flow rates. This buffer storage idea may be the most cost-effective means of increasing the capacity of this pipeline supply to further reduce the use of CHP systems for greenhouse CO_2 production in the Netherlands.

Avoiding unsafe environments

A leak of LPG or natural gas could create an explosive atmosphere in the confined space of the greenhouse. Whilst the lower explosive limit (LEL) of methane in air is 5%, for propane (which is a major constituent of LPG in most countries) the LEL is only 2.1%.

At high levels, CO_2 can be toxic. For humans, the short-term exposure limit, as written into the national occupational health and safety documentation in many countries, is 3% by volume and the long term 8-hour time-weighted average exposure limit is 0.5% by volume. Combustion by-products such as carbon monoxide (CO), oxides of nitrogen (NOx) and sulphur dioxide (SO_2) are also harmful to human health at low concentrations.

With this range of toxic and flammable gases potentially being present in a confined space, a good gas detection system inside the green-house is essential. It should be designed and installed according to the hazards present in the operation. For CO_2 measurement, the NDIR sensor in the dosing control system can double-up as a safety gas detection alarm. However, additional stand-alone systems will be required if detection of the other toxic and flammable gases is also required.

From gas to gas

As we have read, the production of CO_2 gas for greenhouse growing may either be through the in-site combustion of natural gas and other fuels, or direct injection of the CO_2 into the greenhouse. In the second case, if we look upstream in the value chain we will very often find that natural gas was a pre-cursor to the CO_2 gas production. At Nexant, we have a range of market reports and technical studies related to all aspects of the natural gas to chemicals value chain and our World Gas Model is a highly refined tool that enables scenario planning and price estimation based on global and regional supply and demand balances.

The Future of Energy and Chemicals

Nexant offers our clients a suite of products and advisory services with an exclusive focus on the energy, chemicals, and related industries. Using a combination of business and technical expertise, with deep and broad understanding of markets, technologies and economics, we provide solutions that these industries have relied upon for over 45 years.

Our clientele ranges from major oil and chemical companies, utilities, regional and national governments, renewable energy and bio-based materials producers to financial institutions, development agencies and law firms.

Nexant provides a range of consulting and advisory services across multiple industries:

- Strategic Business Advice
- Investment Studies
- Commercial, Technical and Environmental Due Diligence
- Strategic Growth Plans
- Project Feasibility Studies
- Industry Analytics, Forecasting and Market Research
- Litigation Support and Expert Testimony

Nexant Subscription programs and online product search portal provides customers with insightful analytics, forecasts, and planning tools for the chemicals, polymers, oil & gas, energy, and clean tech sectors. For more information regarding our reports and data simulators, please visit: www.NexantSubscriptions.com.

Carbon dioxide dosing, water desalination and carbon capture for greenhouses is one in a series of reports published as part of the 2018 TECH Program. In this report, Nexant has articulated the reasons that CO2 addition are beneficial to crop yields. We have also introduced some of the environmentally-friendly ways that CO2 dosing can be combined with geothermal energy, solar power and sea water desalination to allow nutritious fresh food to be grown in arid coastal areas around the world. Carbon capture and re-use, from sources such as refineries and bio-renewable fuels facilities, is also highlighted to ensure the sustainability of this growing method.

Stephen B. Harrison is Principal, Germany for Nexant. He is located in Munich and has played an active role in developing technology for environmental good practice related to atmospheric emissions reduction, air quality, water treatment and energy management for many years. He writes here on how green agro-tech is being applied to greenhouse farming for high quality and high yield crop production. His team of consultants and his personal expertise are available, through Nexant, to engage in training, workshop facilitation and other consulting work related to implementing innovative environmental best practices in the energy and chemicals sector in the DACH region.

Contact the author for further information on green technologies and environmental best practices, or other consulting engagements in the energy and chemicals sectors.

Stephen B. Harrison
Principal
Sbharrison@nexant.com

