CO2 & LIGHTING

in Closed Environment Agriculture
by Dr. Prashanth Makaram

Introduction

The advent of vertical farms and modern greenhouses has revolutionized the field of horticultural farming, offering innovative solutions to address the increasing demand for sustainable food production.
These controlled-environment agricultural systems utilize advanced technologies to optimize resource usage, maximize crop yields, and minimize environmental impact. However, managing and maintaining optimal growing conditions within these enclosed spaces pose significant challenges. In addition to artificial lighting, one critical factor that significantly affects plant growth and productivity is the concentration of carbon dioxide (CO2).

Problem Statement

In controlled environment agriculture (CEA), such as vertical farms and modern greenhouses, maintaining optimal growing conditions is essential for achieving maximum crop productivity. Two critical factors that significantly influence plant growth are artificial lighting and CO2 concentration. In CEA, optimizing light spectrum, intensity, and duration measured by Daily Light Integral (DLI), is crucial for promoting crop growth and maximizing yields. Unlike us humans, who suffer from higher CO2 concentrations, crops need a certain level of carbon dioxide, typically maintained between 800 ppm (e.g seedlings of tomatoes, cucumbers) and 1300 ppm to be able to grow efficiently and thrive in controlled environments. The lighting needs and CO2 requirements vary depending on the crop variety and its specific stage of growth. The CO2 concentration in tightly sealed CEA growing operations can quickly dip down to 200 ppm, prompting almost all CEA businesses to use CO2 dosing as a compensatory measure to bring the CO2 levels to optimal concentration.

Unlike other environmental factors, CO2 needs to be controlled precisely and is highly affected by ventilation, plant growth period, and weather. CEA facilities often feature ventilation systems and physical structures like racks and trays that impede air movement, resulting in stratification within the environment. Consequently, certain areas may experience suboptimal CO2 concentrations, adversely affecting photosynthesis and overall plant performance. To mitigate this issue, growers increase the overall CO2 levels in the farm by injecting additional CO2. However, growers must exercise caution, as excessive CO2 dosing can lead to imbalanced plant growth, reduced crop quality, and increased operating costs. The imbalance between CO2 supply, crop uptake, and ventilation also contributes to climate change through direct CO2 emissions (i), while mandates for green energy requires farms using boiler heating systems for generating CO2 to explore alternative enrichment systems (ii).

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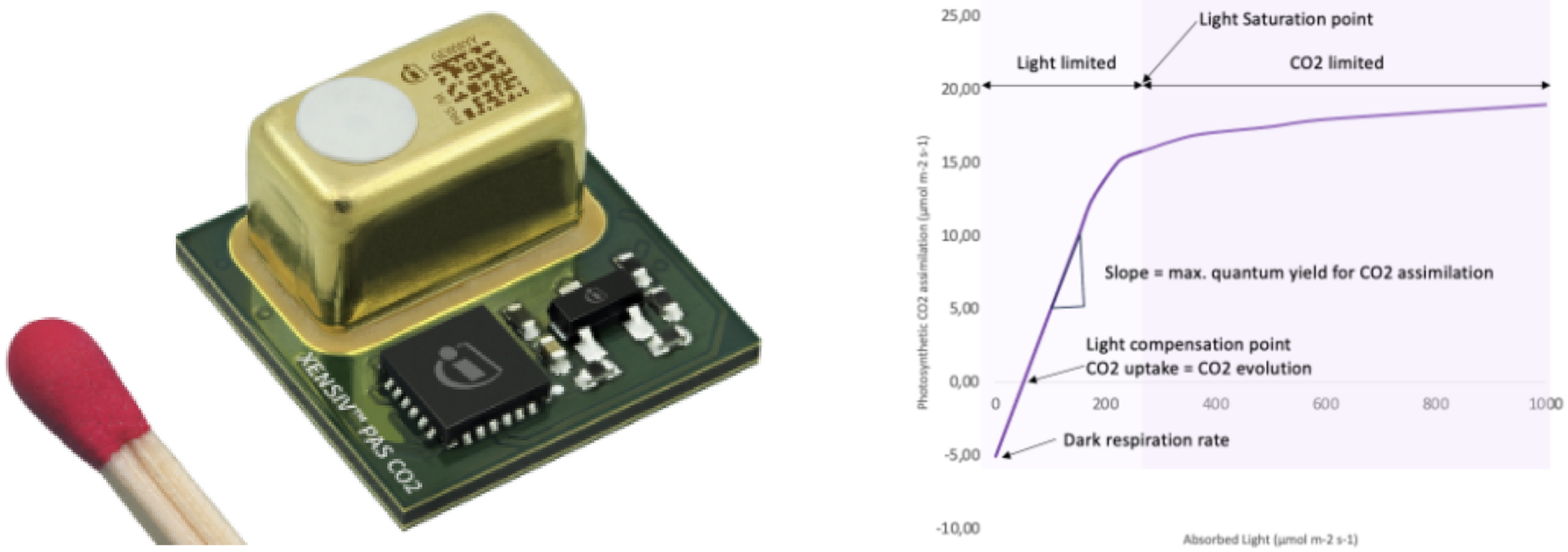
Solution: The perfect match of Infineon Technologies and Crocus Labs

To address these challenges, growers can exploit the relationship between CO2 concentration, light intensity, and photosynthesis to optimize for plant growth and productivity. Figure 1 depicts the CO2 and light intensity curve. By maintaining the right balance of CO2 and light spectra, growers can maximize the quantum yield for CO2 assimilation. However, there is a saturation point where further increases in CO2 and light intensity have minimal impact on photosynthetic activity.

Strategically placing CO2 sensors throughout the cultivation area allows growers to gain comprehensive insights into CO2 distribution and make informed decisions regarding CO2 supplementation and light spectra. Crocus Labs' intelligent lighting system leverages the Infineon XENSIV™ PAS CO2 sensor in order to collect data from different parts of the farm. This seamless integration enables synchronization of the spectral outputs of the lights with the specific CO2 requirements of different plants at different growth stages and at different locations creating an ideal growth environment.
By ensuring even photosynthetic rates tailored to the plants' needs, growers can achieve higher yields, improved crop quality and reduce operating costs (from electricity and CO2 dosing). This ability to precisely control light spectrum and CO2 also offers farms the flexibility to mitigate market risks by adapting their crop selection. For instance, in a scenario where the market becomes saturated with cucumbers, causing a drop in their price, farms can simply adjust the light and CO2 parameters to accommodate a different crop. This adaptability helps them avoid financial losses and maintain profitability.



(left) XENSIV™ PAS CO2 operating inside a vertical farm with the cover open; (right) (iv) Typical light response curve for plants (v)

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By integrating Infineon's highly accurate XENSIV™ PAS CO2 sensor with Crocus Labs' intelligent lighting system, Crocus Labs provides growers with a comprehensive solution that combines real-time CO2 monitoring, precise lighting control, and smart spectral tuning. For instance, in a 10 meters high vertical farm spread over 1000 sq. mts cultivating leafy greens, the integration enables growers to monitor CO2 levels and dynamically adjust the lighting spectra at different locations of the farm to compensate for the loss in optimum CO2 level and thus match the specific needs of the plants. By analyzing the CO2 sensor data and utilizing advanced algorithms, the lighting system can intelligently tune the spectral output to optimize photosynthetic efficiency, promote plant quality while reducing the need for CO2 overdosing.

In another use case, consider a greenhouse cultivating fruiting crops. With the integration of Infineon's CO2 sensor and Crocus Labs' lighting system, growers can finetune the spectral composition of the light based on the real-time CO2 measurements. For example, during the transition from flowering to fruiting stage, the XENSIV™ PAS CO2 helps to maintain uniform CO2 levels, while the Crocus labs lighting system can be tuned to add more red wavelength to improve fruit development. By precisely controlling both the CO2 levels and the lighting spectra, growers can create an ideal growth environment that maximizes the plant's photosynthetic capacity, resulting in vibrant and healthy flowers.

These examples demonstrate how the integration of Infineon's CO2 sensor with Crocus Labs' intelligent lighting system revolutionizes plant cultivation by combining real-time CO2 monitoring with smart spectral tuning capabilities. By monitoring CO2 levels and adjusting the lighting spectra accordingly, growers can optimize photosynthesis, enhance growth, and tailor the light environment to the specific needs of different crops and growth stages. This level of control and customization empowers growers to achieve higher yields, superior crop quality, while reducing the energy needs for CO2 and lighting.

Furthermore, by integrating the Infineon CO2 sensor and Crocus Labs' intelligent lighting system, growers can also harness the power of digital twin technology. The combination of real-time CO2 sensor placed in different locations within the farm along with the precise lighting control helps in creating a virtual representation of the crop's growth environment, known as a digital twin. This digital twin enables growers to simulate and optimize various growth scenarios by adjusting CO2 levels and spectral tuning parameters virtually. By leveraging data-driven insights from the digital twin, growers can make informed decisions about lighting strategies, CO2 supplementation, and overall crop management, leading to improved resource efficiency, minimized risks, and enhanced crop performance. The integration of the CO2 sensor and intelligent lighting system with digital twin technology brings a new dimension of control and optimization to horticultural farming, enabling growers to unlock the full potential of their crops.

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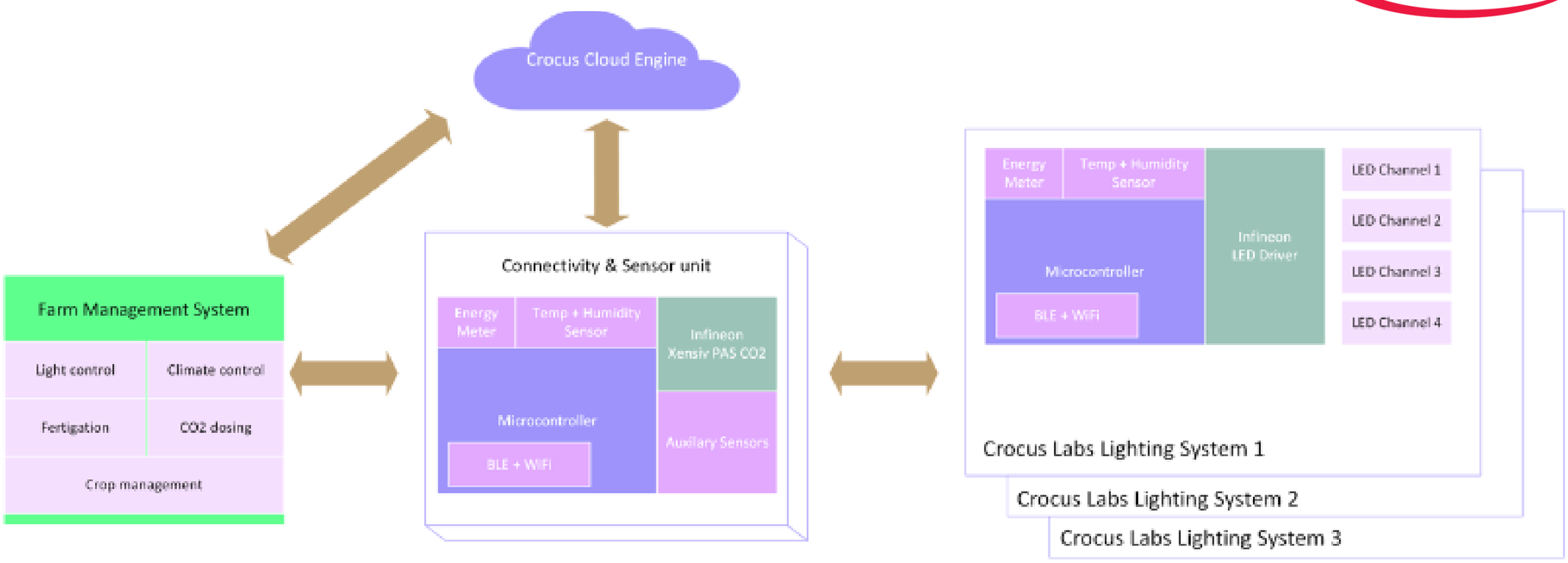

Figure 1: Block diagram

The benefits of CO2 sensors

The XENSIV™ PAS CO2 sensor from Infineon is perfect for the purpose of carbon dioxide monitoring and management as it overcomes the limitations of traditional CO2 sensors such as cost, size, performance, and assembly challenges. Especially the compact design, the superior accuracy and performance stability over time make it an ideal choice for integration into Crocus Labs' light system. This integration enables precise monitoring of CO2 concentration across the entire farm, eliminating any hotspots and ensuring uniform plant growth. The combination of Infineon's high-efficiency LED driver chips with these technologies offers growers a comprehensive solution that enables accurate CO2 monitoring and efficient light control. This integrated approach maximizes crop productivity while minimizing CO2 waste and providing an optimized solution for indoor farming.

Summary

Maintaining optimal CO2 levels in Controlled Environment Agriculture (CEA) poses significant challenges due to the critical interaction between CO2 and light, which directly affects photosynthetic rates and, consequently, plant quality and yield. Currently, growers often use energy-intensive practices such as excessive lighting or CO2 overdosing to address this issue.

However, by incorporating the advanced Crocus Labs lighting solutions as well as the highly accurate XENSIV™ PAS CO2 sensor, growers gain the ability to accurately measure CO2 levels throughout their farms. Armed with this data, they can then finetune the light spectra to maintain optimal photosynthetic rates. As a result, this synergistic approach leads to higher crop quality and increased yield, all while reducing energy consumption and overall costs. By leveraging these innovative technologies, growers can elevate their CEA practices, achieving both environmental sustainability and enhanced productivity.

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About Crocus Labs

Crocus Labs GmbH is a Berlin/Brandenburg based startup. Crocus Lab's mission is to empower the world's transition to sustainable food through increasingly sun-like, efficient light technologies for Greenhouses, Vertical farms and all other forms of closed environment agriculture.

By leveraging proprietary semiconductor technologies, Crocus Labs can produce groundbreaking LEDs with best-in-class performance. As the world's only vertically integrated horticulture luminaire system company, Crocus Labs continues to innovate, scale and reduce the costs of operating indoor farms while improving crop quality, with the goal of ultimately getting us to a sustainable and 100% locally sourced food that is accessible to all.

For more information, please reach out to galina@crocuslabs.com

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