Guidelines for greenhouse management

aranet

Setting the Greenhouse Management Goals

Modern greenhouses are filled with technologies and systems to monitor and control the growing environment and follow up on the growing process of plants. Modern solutions typically include automated windows, climate control with ventilation and heating systems, irrigation, and nutrient delivery systems, etc.

Aranet ecosystem allows you to communicate with your greenhouse to make the right decisions and avoid guessing. **Monitor environment and fine-tune growing operations** to maximize yield.

In greenhouse climate control, achieving the ideal conditions relies on proper ventilation and heating systems, CO_2 dosing, and lighting management using screens and artificial lights. These technologies aim to maintain optimal temperature, relative humidity, CO_2 levels, and daylight exposure throughout the greenhouse. Precise conditions not only enhance growth and yield but also prevent issues like condensation, which can trigger disease outbreaks, and ensure uniform conditions across the greenhouse.

While it is crucial to monitor the climate throughout the greenhouse, effective plant growth monitoring can be achieved by employing one or a few reference plants equipped with sensors. These reference plants provide valuable feedback on irrigation, salinity, biomass gain, and other critical parameters, facilitating informed decision-making for all plants in the greenhouse.

Follow up-to processes in the greenhouse by measuring and calculating parameters like:

Ambient conditions

- Air temperature (T)
- Relative humidity (RH)
- CO_2 concentration
- Photosynthetically active radiation (PAR) light level
- Daily light integral
- Dew point
- Vapor pressure deficit (VPD)

Plant growth processes

- Plant leaf temperature
- Weight of the plants and fruits
- Micro-variations of stem diameter
- Sap flow in stem

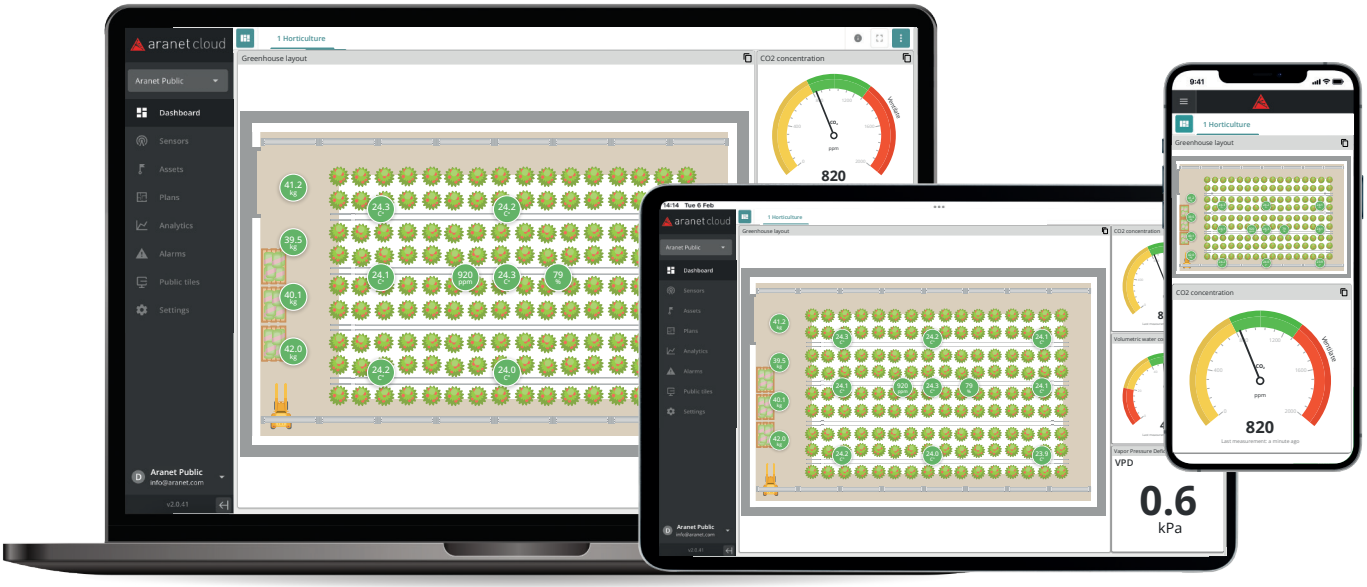
Root zone conditions

- Volumetric water content (VWC)
- Salinity (EC) level
- Electrical conductivity in pores (ECp)
- Temperature
- Drainage water volume

How does the Aranet ecosystem work?

Example of wireless sensor and base station installed in the greenhouse.

The Aranet solution utilizes **wireless sensors** that transmit data readings to the centrally located base station (gateway). This offers ultimate flexibility in moving the sensors around to find the most suitable placement, independently of any wiring. Select the measurement interval of each sensor from 1 to 10 minutes depending on the dynamics of the parameter and battery life preference. Most of the sensors operate on standard AA or AAA batteries, providing a lifespan of over 5 years.
If the base station is connected to **Aranet Cloud**, greenhouse **data is available from anywhere and anytime!** Manage data and Aranet devices from several greenhouses by using the Cloud platform. Cloud provides notifications when some parameters are out of specific range, data analysis, calculation options (virtual sensors), and other features. Share data with colleagues and agronomists for specific feedback.



Manage data and Aranet devices from several greenhouses by using the Cloud platform.

Aranet ecosystem can be integrated with 3rd party control systems by using MQTT, Modbus TCP/IP, and BACnet IP protocols, as well as Cloud API can be integrated with any Web or cloud-based IT system or used as a data source for 3rd party applications.

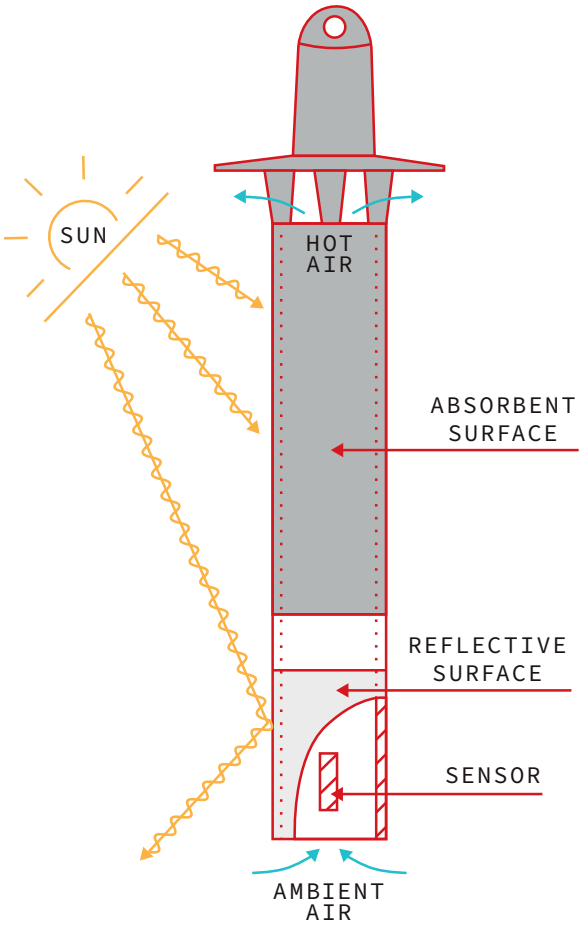
Aranet is compatible with solutions from PRIVA, Argus Controls, Damatex, 30 MHz, Ledgnd, Source.ag, Grownetic , LetsGrow.com, Blockbax, Ageon, HortiAdvice, Trym, Hoogendoorn.

Measuring T/RH under sunlight

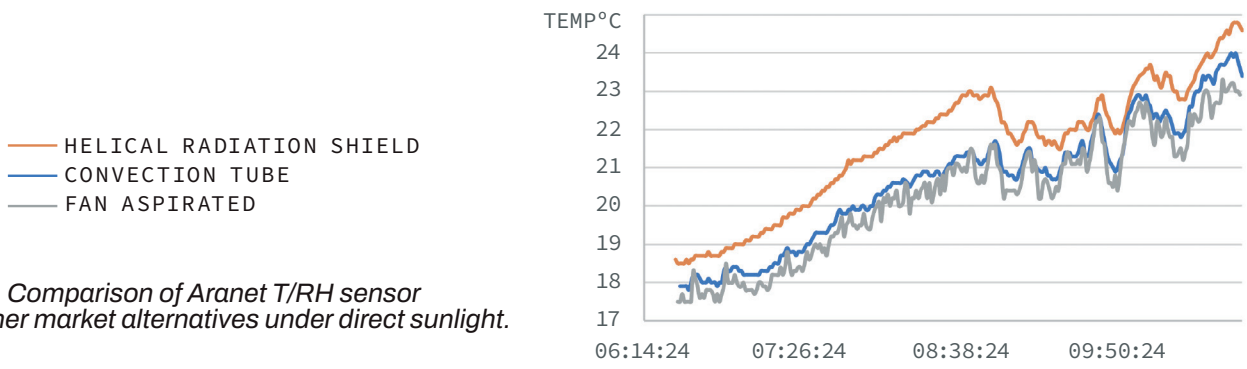
The Aranet T/RH sensor with Convection Radiation Shield is essential for accurate temperature and humidity measurements in greenhouses exposed to direct sunlight. Its innovative design, featuring a tube divided into reflective and black-coated segments, creates a passive ventilation flow. This prevents sensor heating and ensures precise readings, making it a vital tool for greenhouse monitoring.

In experiments, a difference of up to 7°C (≈ 15°F) is observed between regular T/RH sensors and those with a Radiation Shield, underscoring the importance of opting for the shielded sensor. Given the potential error in temperature measurements, especially in critical conditions for plants in unfavorable climates, accurate sensors are essential. Comparing the Aranet T/RH sensor with Convection Radiation Shield to other market alternatives, it outperforms passive solutions like helical radiation shields and rivals actively cooled fan-based solutions, all at a fraction of the cost.

T/RH sensor with Radiation shield installed in the greenhouse.



Working principle of the sensor.



Comparison of Aranet T/RH sensor and other market alternatives under direct sunlight.

Optimize temperature and relative humidity distribution in the greenhouse

Choose the Aranet T/RH sensor to monitor temperature and relative humidity for all stages of plant growth. This temperature and relative humidity sensor has Ingress Protection class IP67 - dust and waterproof - meaning it can be placed in harsh environmental conditions. If the greenhouse is exposed to direct sunlight, use this sensor in conjunction with a T/RH sensor with a Radiation Shield to obtain precise information about the climate inside the greenhouse.

By installing this sensor at different areas within the greenhouse and various heights (top, midsection, and bottom) of plants, you can monitor temperature fluctuations resulting from uneven ventilation, sun exposure, or heating. These factors can influence yield in different areas of the greenhouse. Utilize measurements to calculate parameters like Dew Point, Vapor Pressure Deficit (VPD), and other virtual sensors, such as average parameter values. Diagnosing inhomogeneities provides an advantage in adjusting the climate control system, including heaters and ventilation, based on data-driven results.

T/RH sensor installed in the greenhouse.

Role of carbon dioxide (CO_2) in plant growth

Carbon dioxide (CO_2) is one of the key ingredients of photosynthesis, it is essential for plant growth. Monitoring CO_2 levels in a greenhouse enables the optimization of environmental conditions, leading to more efficient plant growth and higher crop yields. Different plants require varying CO_2 concentrations in the air to maximize their growth rates.

CO_2 and Temperature sensor installed in the greenhouse.

The CO_2 concentration needed depends on the plant type, for most crops optimal growth is when CO_2 is in the range 800 – to 1300 ppm (parts per m illion).

Active photosynthesis can reduce the greenhouse CO_2 concentration to as low as 200 ppm, negatively impacting plant growth. Insufficient CO_2 limits growth, while excessively high levels are also detrimental. Plants are more sensitive to elevated CO_2 concentrations than humans – plants can show damage like burnt leaves at high CO_2 levels.
Use Aranet CO_2 and temperature sensor to track CO_2 levels in the greenhouse.

PAR – the amount of light available for plant photosynthesis

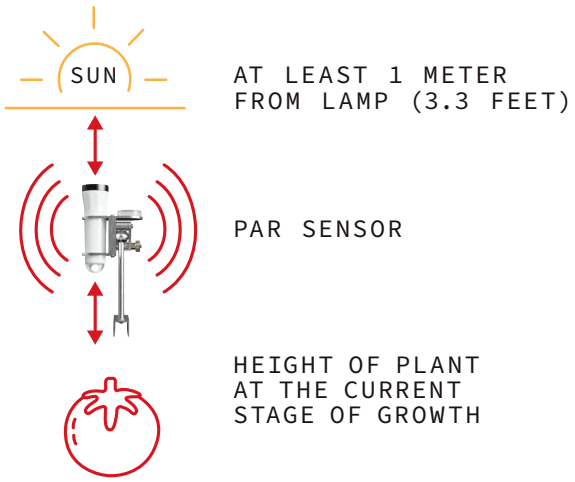
The photosynthetically active radiation (PAR) sensor measures the amount of light radiation (within 400 – 700 nm) that your plants are exposed to. The total amount of light radiation comprises sun radiation plus any artificial source of light from specialized light bulbs or LED lamps.

PAR sensor installed in the greenhouse.

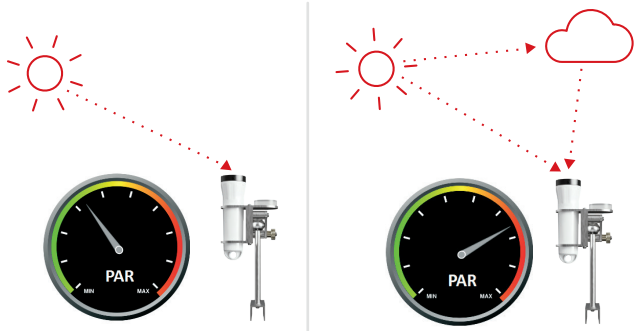
Each crop has an ideal light intensity for maximum photosynthesis and growth. Insufficient light leads to decreased growth and crop quality, while excessive light does not enhance photosynthesis and growth, despite the energy cost of maintaining high light levels. PAR measurements can be used to **evaluate the value of daylight integral (DLI)** – the amount of PAR light received during 24-hour time period. **Optimize artificial lighting strategies** by increasing or reducing based on the levels of natural light received.

Place the PAR sensor where it receives uniform light from various LED lamps. Position it at least one meter below the LED lamps, aligning it with the current height of your growing plant.

What might influence the measurements?
The PAR sensor measures light in micro-moles per square meter second (µ mol/s/m2). Meaning, it counts the number of photons – particles of light – that hit the surface area of the detector every second. The surface of the detector is flat, so the angle of the light also matters.



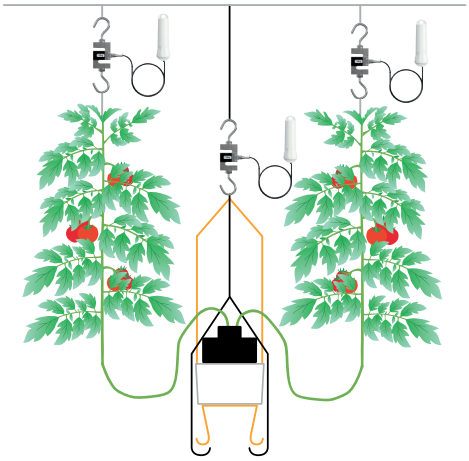
Recommended placement for PAR sensor.



Sunlight reflected off clouds may affect PAR measurements.

Uneven readings in PAR sensor measurements can typically be attributed to two factors. Firstly, as the sun moves across the sky, shadows cast by the greenhouse structure cause drops in the curve. Secondly, during certain times in the morning and evening, jumps in the measurement occur due to sunlight being reflected from clouds, in addition to the direct sunlight. This reflects a higher PAR reading during such instances.

Optimize Plant Growth and Yield with Aranet Weighing Solutions



Schematic of the multiple weight sensor system.

Example of using a Weight sensor with a frame for plant growth monitoring.

Continuous weight measurement with the Aranet Weight sensor enables monitoring of various factors, including **biomass increase, plant weight, how much water is added, and drainage weight.** The sensor offers accurate real-time data, eliminating the need to relocate objects or plants for weighing—objects can be suspended permanently. These measurements facilitate **long-term tracking of growth progress until harvest.** Combine multiple weight sensors to obtain more detailed information about processes in the greenhouse. Aranet Cloud platform allows the creation of virtual sensors to calculate the difference or sums between the measurements.

Aranet Weight sensor with frame. Consistent, precise, and conveniently managed weighing of the seedlings is important for a successful horticulture operation. The combination of Aranet and Voshol technology enables wireless and **continuous seedling weighing, ensuring consistent and easy access to weight data.** Plants can now be weighed in their cultivation trays. When compared to other weight scales, **this solution provides more representative readings** – because all plants within a tray are in a similar condition. Each of the frame's corners has adjustable screws to ensure perfect leveling and prevent uneven water distribution.

Track substrate moisture and EC

WET150 sensor equipped with an installation bracket for monitoring VWC, EC, and temperature in substrate

Example of Soil Moisture sensor installation.

Aranet offers two types of sensors to **monitor processes in the plant's root zone**, measuring parameters such as substrate moisture, volumetric water content (VWC), electrical conductivity (EC), and temperature.

The Aranet Soil Moisture sensor is designed exclusively for growing applications. By placing the sensor in the plant's root zone, growers can monitor soil moisture levels and analyze the data to make data-based irrigation decisions. Multiple sensors may be employed for enhanced precision, particularly when dealing with uneven soil moisture content.

Aranet WET150 is the new standard in VWC monitoring! Ensure plants have the correct amount of water and nutrients by monitoring **VWC, temperature,** and EC – a strong indicator of the general nutrient level. Use WET150 for both soil **(indoor and outdoor)** and soilless substrates in greenhouses. An important feature of the WET150 is its ability to reliably calculate **pore electrical conductivity (PEC or ECp)**, which represents nutrient levels of the water available to the plant. In the Aranet platform, users can choose between substrate types from a proposed list or calibrate specific substrates in our laboratory.

Experience shows that sensor placement precision has a high influence on measurements. Poor or inaccurate sensor placement is a common cause for significant data variations from one plant to another and one room to another.

To ensure consistent data collection throughout your growth cycle, Aranet has designed WET150 Sensor Installation accessories, enabling precise sensor installation for every plant, every time.

Installation example of WET150 sensor with sensor holder installed in the tomato greenhouse.

Evaluate VPD by knowing the leaf temperature

IR Plant Temperature sensor installed in the greenhouse.

Vapor Pressure Deficit (VPD) informs about the impact of humidity on plant growth. VPD measures the difference between the moisture in the air and how much moisture the air can hold at a given temperature. For accurate VPD evaluation, it's crucial to have precise plant temperature data. The Aranet IR Plant Temperature sensor is designed to measure the surface temperature of plant leaves, making it a valuable tool when combined with T/RH measurements in a greenhouse to calculate VPD.

When the VPD level is high, meaning air is relatively dry, the plant experiences increased pressure. This increases the transpiration rate and plants consume more water. Inadequate watering in such conditions can lead to the wilting of plants. On the other hand, if the VPD level is low, the plant will transpire less. In such conditions, it is important not to overwater the plant.

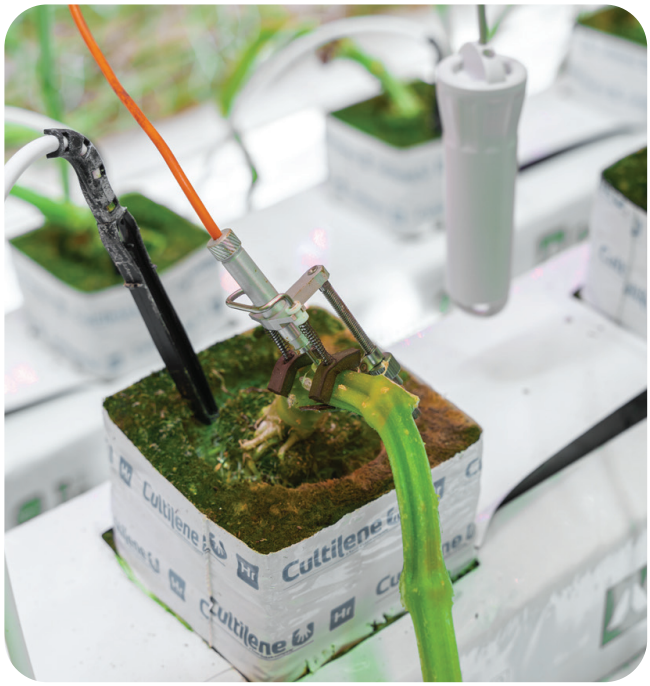
Know the drainage water volume from plants

Accurately measuring the volume of water drainage from the greenhouse system empowers growers to precisely adjust their irrigation practices. This precision ensures that plants receive optimal water levels, avoiding both over- and underwatering scenarios. Consequently, this practice conserves valuable water resources while simultaneously mitigating problems like waterlogging, nutrient leaching, and root diseases.

The Drainage Sensor Kit employs a specialized funnel with a 50 cm2 orifice to effectively measure fluids. The liquid is directed into a self-emptying bucket, managed by a magnet that is precisely calibrated for quick tipping (in less than 300 milliseconds) and rapid return to its regular position. This innovative design enables the efficient collection of excess water from the substrate or soil. Apply the Drainage sensor within your greenhouse's drainage system, and ensure the implementation is tailored to suit your specific system and needs.

Representation of the Drainage sensor.

Study micro-variations of stem diameter



Example of Stem Diameter sensor installed in the greenhouse

Investigate the effects of irrigation rate and other environmental factors on water balance and growth of plants by using the Aranet Stem diameter sensor kit.

This **sensor tracks changes in the plant's stem diameter with micron-level accuracy**, enabling the detection of plant responses to growth factors. These measurements provide valuable insights for optimizing ventilation, light screening, and irrigation strategies for enhanced plant health and growth.

Two diameter-based indices commonly employed to assess plant water status are the daily contraction amplitude and the trend of daily maxima. Apply stem diameter variation measurements in combination with sap flow measurements to study the growth factors in detail.

Sap flow measurements in stem

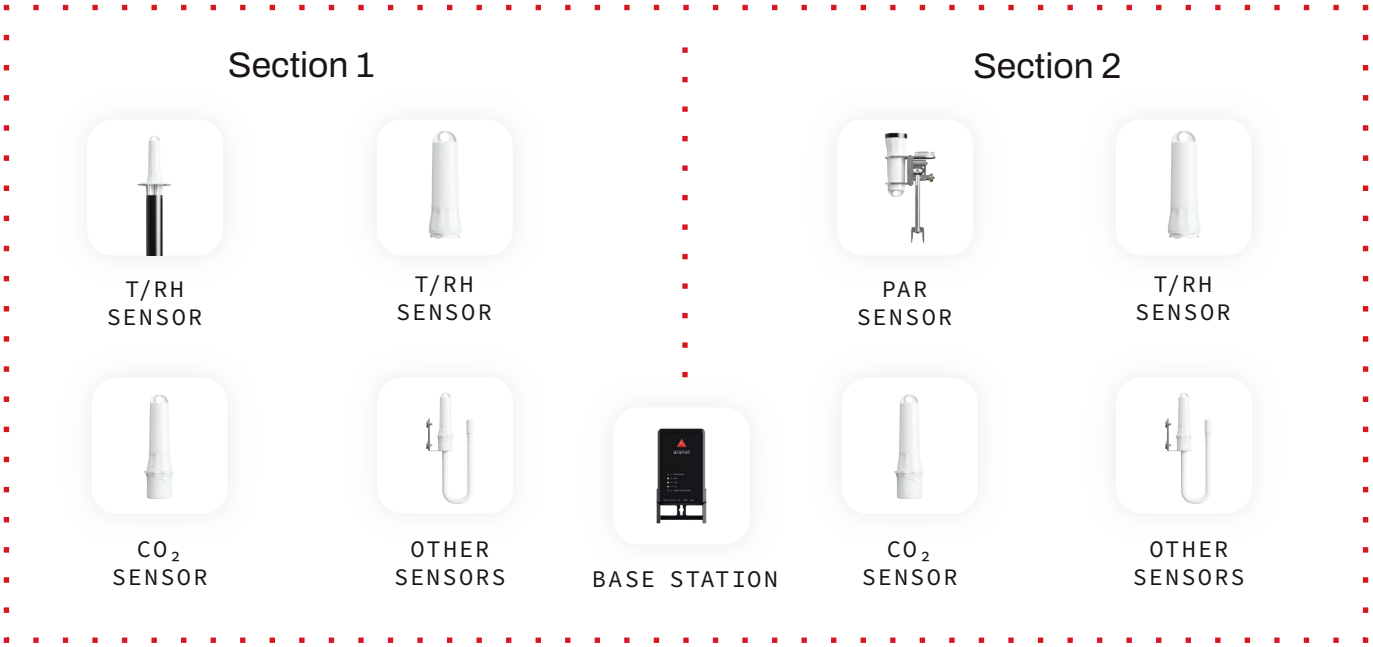
Example of a reference plant in the greenhouse equipped with SAP flow sensors to study flow in both stem directions, along with a Stem Diameter sensor.

The Aranet SAP Flow sensor kit is designed to monitor relative variations of sap flow rate in plants petiole or small shoot. The sensor surrounds the petiole and, by locally heating the plant, detects sap flow response. Apply sap flow measurements in combination with stem diameter variation measurements to study the growth factors in detail.

The sensor is suitable for stems with diameters of 4 to 10 mm.

How many sensors do I need?

The number of sensors needed per section depends on the desired precision and specific monitoring parameters. Monitoring processes can be categorized into two main parts.



Schematic example of sensors installed in the greenhouse.

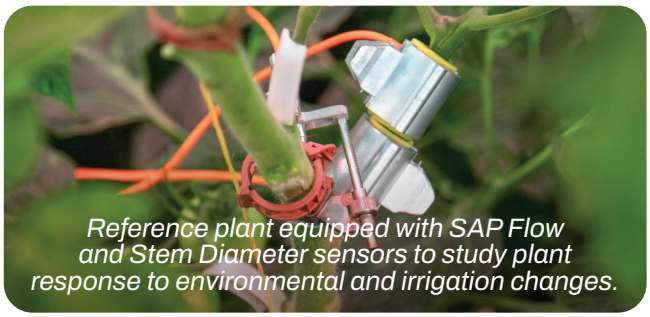
Firstly, sensors for ambient greenhouse conditions such as temperature (T), relative humidity (RH), CO_2 concentration, and lighting. While one PAR and CO_2 sensor per greenhouse section may suffice, multiple T/RH sensors are typically required. For instance, consider using one T/RH sensor with a radiation shield for each greenhouse section, supplemented by additional T/RH IP67 sensors strategically placed throughout individual growth zones to capture comprehensive ambient conditions. For more detailed insights on T/RH sensors, refer to the corresponding sections.

Example of PAR, T/RH with a Radiation shield, and CO_2 sensors installed in the greenhouse to monitor ambient conditions

Secondly, sensors for root zone conditions and other specific parameters, such as volumetric water content, stem diameter variations, etc. To gain insights into specific growth processes and receive feedback from plants regarding irrigation and other conditions, it is essential to establish reference plants that are monitored in detail. Typically, one sensor for each parameter being studied per reference plant is necessary to ensure accurate monitoring and comprehensive analysis. Apply decisions made from reference plants to other plants in the greenhouse.

Add up to 100 sensors per base station to achieve detailed monitoring of your greenhouse, if needed.

Reference plant equipped with a WET150 sensor to track root zone conditions.



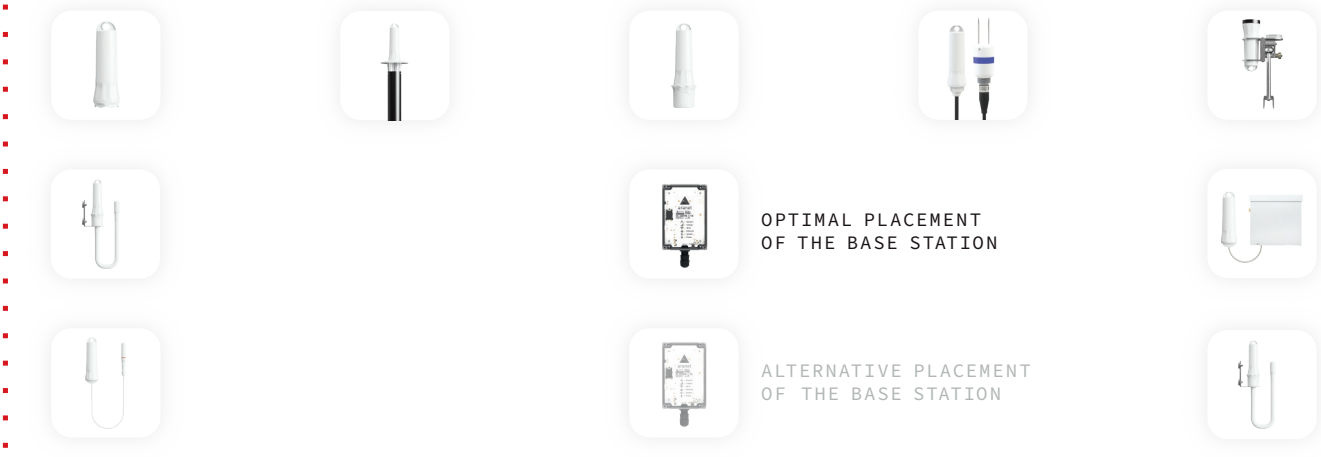
Reference plant equipped with SAP Flow and Stem Diameter sensors to study plant response to environmental and irrigation changes.

Example of the Base station installed above the tomato plants in the greenhouse.

Position of the base station

For optimal performance, position the base station centrally to receive data from all sensors. Mount it at a height above the tallest plants. If a central location isn't feasible, choose a convenient spot that ensures strong signal reception from all sensors, even the farthest ones. Utilize the RSSI sensor to optimize base station and sensor placement.

According to our observations, the distance between base station and sensors can be up to 100 – 150 meters (350 – 500 feet) in a typical greenhouse (steel construction, glass walls with few gates/doors).



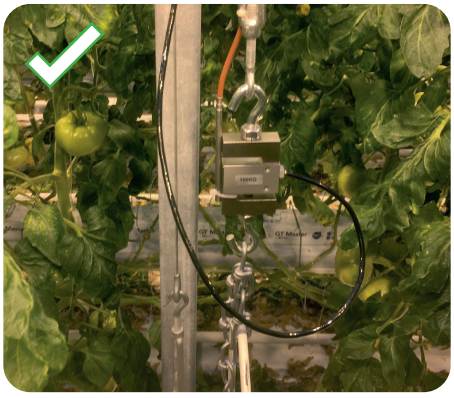
It is recommended not to position the sensor transmitter (white body) surrounded by leaves.

General guidelines for sensor placement

Every greenhouse is unique, with its distinct air environment and plant growth processes. Aranet wireless sensors offer you complete freedom to experiment with sensor placement—try different configurations until you find what works best for your greenhouse.

The large water content in plants and fruits is the primary factor contributing to the weakening of the radio signal if sensors or the base station are positioned too low. If the sensor with an extended wire to a transmitter is used, **position the sensors** approximately one foot or 30 centimeters **above the expected maximum height of the plants**. We recommend placing the **base station as high as possible** for optimal signal strength.

Example of the Base station installed above the tomato plants in the greenhouse.



Example of installation: Sensor part positioned at the desired location.

If the sensor has an extended wire, position the transmitter (white body) above the plants.

It is recommended not to position the sensor transmitter (white body) surrounded by leaves.

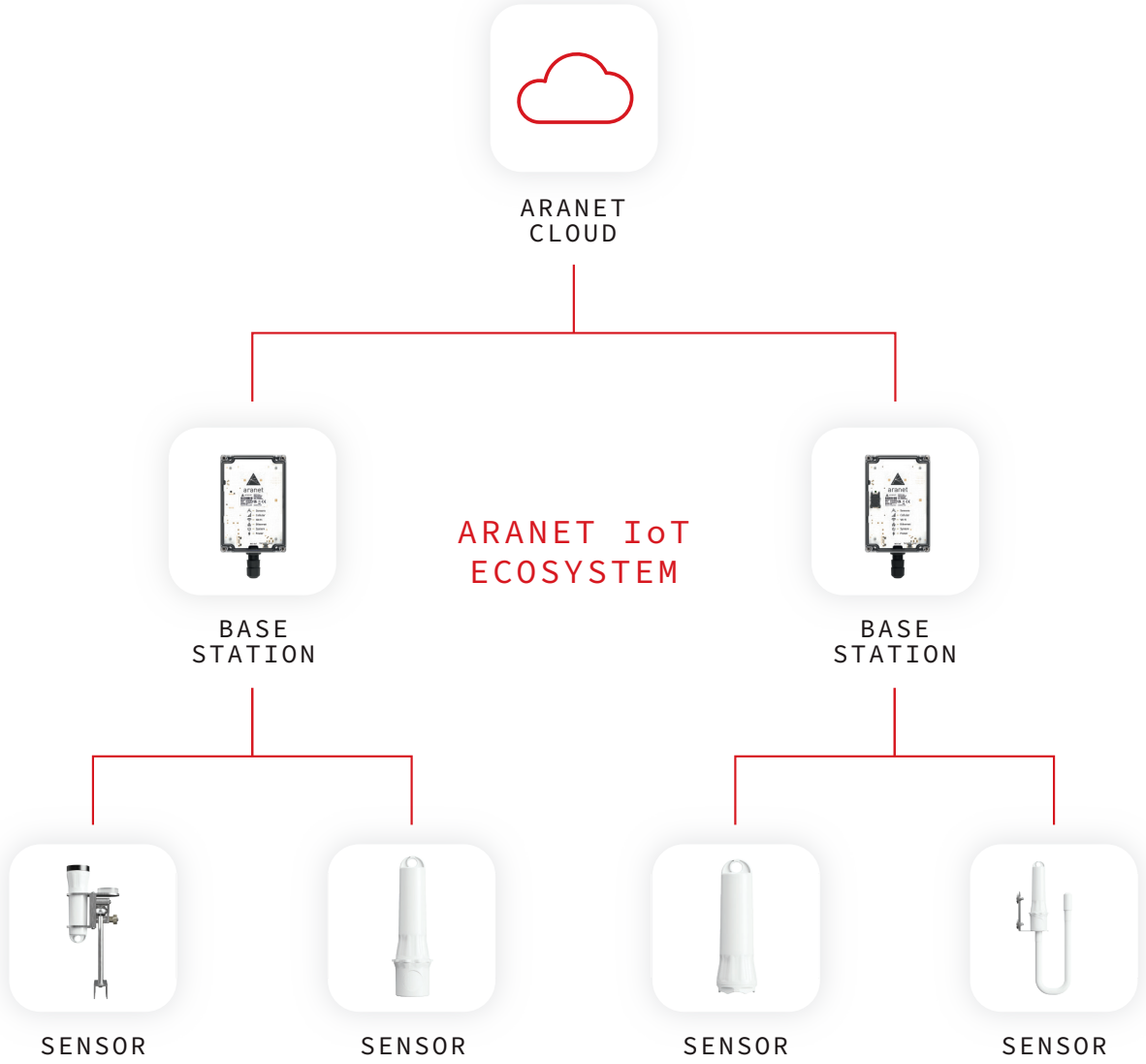
Efficient greenhouse performance

Improving energy efficiency not only reduces operational costs for greenhouse operators but also minimizes the environmental impact associated with energy consumption. Monitoring equipment energy consumption, working hours, and water usage enables operators to identify areas for potential improvement. Aranet sensors can detect filter problems or pinpoint ventilation system issues by identifying hot and cold spots within the greenhouse. Visit Aranet.com for the full Aranet PRO series product list.

All three key monitoring components – ambient conditions, reference plants, and energy consumption - are crucial for complete greenhouse monitoring, enabling data-based decision-making, issue prevention, and performance enhancement.

Getting Started with Aranet

Ready to enhance your business with Aranet's monitoring solution? Contact us to discuss your needs and discover how Aranet can support your commitment to data-driven decision-making.



Sensors

A variety of wireless sensors that monitor conditions indoors and outdoors

Base stations

One or multiple base stations that gather and store data from sensors

Cloud

A cloud service to access, view, and analyze all your data in one place