ChatGPT

Indoor Farm Dashboard Equipment & Application Recommendations

This report reviews the proposed Farm Profile wizard and recommends equipment and software tools to support the features described. It uses recent sources to identify modern sensors, controllers and platforms and highlights opportunities to simplify configuration, maximise interoperability and support data-driven AI features.

Farm Profile & Intake Flow

The wizard approach you propose will gather basic farm metadata, group definitions and device counts. Keeping the questions natural and progressive is essential to reduce cognitive load. It's worth implementing a few features to support this:

1. **Type-ahead device selection and knowledge base** – Building a small knowledge base of common grow lights, HVAC units and sensors will allow the wizard to auto-populate fields like wattage, driver type and spectrum. For lights, store each model's rated wattage, control options (0-10 V, Modbus, LAN API or BLE) and spectral distribution so the user only selects the model. Photos of nameplates or datasheets can be accepted and parsed later for missing models. Use coarse spectral bins (20–40 nm) to enable the spectrum bar described later.

2. **Micro-forms for environmental equipment** – Each environmental device (HVAC, dehumidifier, stand-alone AC/heat, fans) should use a short, 3-tap form: number of units, control method and energy metering. This avoids long text fields and quickly determines whether the unit is hard-wired, uses Modbus/BACnet, Wi-Fi, IR remote or a smart plug.

3. **Sensor selection** – Provide chips for common sensor categories (temperature/humidity, CO_2, dewpoint, light/PPFD, energy, water flow/EC/pH). Ask where each sensor is located (room, zone, canopy, intake/exhaust) using quick pickers. For outdoor baselines, offer a local weather API or an outdoor probe.

4. **Connectivity** – Confirm the presence of a local hub (reTerminal or similar) and ask for the IP/hostname, then confirm the Azure tenant for cloud connection. Use a role picker to assign who can edit farm settings.

5. **Setup queue** – Each affirmative answer should add a 'todo chip' to a queue that launches the corresponding device onboarding card. This prevents half-configured devices from being forgotten.

Implementing this wizard with a low-code platform such as **Node-RED** can accelerate development. Node-RED is a low-code IoT tool with a web-based editor and a large library of connectors. It is widely used for quick prototyping and is stable enough to be used in production; it also supports Modbus and MQTT communication. Node-RED flows can poll Modbus devices and forward data via MQTT to a cloud backend [1]. The platform runs well on a Raspberry Pi or reTerminal and has a dashboard module for rapid UI prototypes [2].

Lighting Hardware & Integration

Indoor farms use a mix of proprietary horticulture fixtures and commodity LED grow lights. To ensure broad compatibility, adopt a multi-protocol approach.

Recommended Lighting Equipment

- **Lights with open control interfaces** – Choose fixtures that support **0-10 V dimming**, **Modbus** or **IP APIs**. These standards allow you to control intensity and spectrum from a central gateway. For example, the **Shelly Plus 0-10 V Dimmer** can remotely control any 0-10 V driver over Wi-Fi; it provides schedules, min/max brightness, night mode and local automation [3]. It works stand-alone or via cloud, exposing a web interface for configuration [4]. Such controllers can dim lights, fans or valves and integrate through MQTT or HTTP.
- **Modbus-enabled ballasts** – Many commercial fixtures (e.g., Gavita, Fluence) use RS-485/Modbus for group control. Modbus energy meters are widely used in industrial settings; they monitor voltage, current and power factor for each phase and allow high-resolution data logging. Using Modbus simplifies wiring (multi-drop) and supports both single-phase and three-phase systems with load balancing and fault detection.
- **Smart plugs with energy monitoring** – For low-cost, non-dimmable fixtures or small fans, Wi-Fi smart plugs with energy metering (≥15 A) are ideal. Devices like the Greenlite Wi-Fi smart plug provide schedules, remote on/off, voice control and real-time and historical energy consumption [5]. They can be paired with the Shelly or Sonoff ecosystems and integrate via MQTT or REST.
- **Handheld or fixed PAR/PPFD sensors** – To validate target vs. actual light intensity, provide reference PAR sensors in each room. These sensors connect via analog (0-5 V) or Modbus and enable calibration of light cards. Portable meters are essential for research mode.

Integration Approaches

- **0-10 V bridging** – Use smart dimmer modules (e.g., Shelly Plus 0-10 V) to convert network commands to analog voltage. These controllers support schedules, webhooks and local scripting [6]. They also integrate with third-party automation systems via MQTT or REST.
- **Modbus/MQTT gateway** – Deploy a Modbus–MQTT bridge on the reTerminal. Node-RED can poll Modbus registers and publish updates via MQTT. Many hardware vendors supply Node-RED nodes for their devices [7].
- **Energy measurement** – When built-in meters are unavailable, install DIN-rail energy meters with CT clamps (e.g., Eastron SDM72M). CT sensors are non-invasive and safe, whereas in-line meters require rewiring but provide higher accuracy [8]. Smart plugs monitor individual devices but are unsuitable for whole-room loads [8]. Use branch-circuit meters for each zone to enable farm-wide energy breakdowns.

Environmental Control Equipment

Temperature and Humidity

Temperature and relative humidity are the most critical variables for plant health. NTC thermistors and RTD sensors are the primary options. **NTC thermistors** are cost-effective, sensitive and easy to install [9]; they provide precise air or soil temperature readings for small farms. **RTD sensors** offer high accuracy but are more expensive [10]. For humidity, **capacitive sensors** are preferred because they provide high accuracy (±2–5 % RH), stability, and long lifespan [11]. Resistive sensors drift over time and are less suited for controlled agriculture [12].

Choose room-grade temperature/RH sensors that communicate via Modbus, Wi-Fi or BLE. **SwitchBot Meter** is an example: it uses a Swiss-made sensor to provide accurate temperature (±0.2 °C) and humidity (±2 % RH) readings and supports local alerts via Bluetooth or remote monitoring when paired with a SwitchBot Hub [13]. The hub relays BLE data to Wi-Fi and allows you to access readings and alerts through an app [14]. Battery-powered sensors can be placed in canopy and root zones; for permanent installations use wired Modbus sensors.

CO_2 Monitoring

Carbon-dioxide levels impact photosynthesis and plant health. **NDIR (non-dispersive infrared) CO_2 sensors** are the industry standard because they detect CO_2 by measuring infrared absorption. The SenseCAP SOLO CO_2 5000 sensor supports Modbus RTU over RS-485 and SDI-12, features built-in calibration, covers a range of 400–5000 ppm, and provides ±(50 ppm + 5 % of reading) accuracy [15]. Its NDIR technology allows continuous measurement, and the protective PTFE filter improves reliability [16]. Use one sensor per room and optionally per zone to track CO_2 consumption; connect them via RS-485 to the reTerminal and calibrate annually.

HVAC, Dehumidifiers and Stand-Alone Units

1. **Central HVAC** – When a farm has central heating and cooling, ask whether it is a packaged rooftop unit, split system or VRF. Many commercial units provide Modbus/BACnet control via RS-485 or IP. If not, connect a thermostat with Wi-Fi or Zigbee for remote set-point control. Where direct control isn't available, smart plugs or relay modules can switch compressors or fans; however, avoid switching heavy loads without soft-start capability.

2. **Dehumidifiers** – Ask the pints-per-day rating (small/medium/large) to set expected kWh ranges and monitor performance. Many industrial dehumidifiers offer remote control via Modbus or 0-10 V; consumer models can be monitored via smart plugs with energy metering. Install branch-circuit energy meters to detect over-consumption.

3. **Stand-alone AC/heat units** – Portable AC or mini-split units may not expose a control interface. Use IR blasters (e.g., Broadlink RM4 Pro) or SwitchBot Hub to send IR codes; schedule on/off times and adjust set points. For devices with 0-10 V inputs, use a dimming controller like Shelly Plus 0-10 V [3].

4. **Fans** – For small oscillating or high-air-flow (HAF) fans, smart plugs suffice; for inline fans, use 0-10 V drivers or variable-frequency drives (VFDs) connected via Modbus. When using a VFD, capture its control address and assign it to a zone or group.

Water & Nutrient Monitoring

While not explicitly requested, many indoor farms benefit from monitoring water flow, electrical conductivity (EC) and pH. Use pulse-based flow meters on irrigation lines; EC/pH probes with BNC connectors and temperature compensation can be interfaced via analog or RS-485. Log values with Node-RED and send to the dashboard.

Sensors & IoT Platform Integration

Sensor Recommendations

- **Temperature & humidity sensors** – NTC thermistors and capacitive humidity sensors provide economical and sensitive measurements [9] [11]. Use sensors with Modbus or BLE outputs.
- **CO_2 sensors** – NDIR sensors such as the SenseCAP SOLO CO_2 5000 offer high accuracy and support Modbus RS-485 or SDI-12 [15].
- **PPFD/Light sensors** – Use spectrally calibrated quantum sensors to measure PPFD and verify light intensity. Connect via 0–5 V or Modbus.
- **Power meters** – Deploy a combination of CT-based branch energy meters (e.g., Eastron SDM72M) and smart plugs with energy monitoring. CT sensors are non-invasive but need a data logger; in-line meters require rewiring but offer revenue-grade accuracy [8]. Smart plugs monitor individual devices and are ideal for portable units but cannot measure whole rooms [8].
- **Water quality sensors** – Use RS-485 or analog EC/pH sensors with temperature compensation; choose sensors rated for continuous immersion.

Platform & Protocols

- **MQTT** – Use MQTT as the backbone for device communication. Node-RED can publish sensor readings and control commands to topics; Azure IoT Hub can ingest MQTT messages for cloud storage and analytics.
- **Modbus RTU/TCP** – Many industrial devices support Modbus. Home Assistant's Modbus integration allows multiple connections and supports sensors, lights, covers and fans [17]. Modbus devices can be polled over RS-485 or TCP and mapped to dashboard entities.
- **BLE and Zigbee** – Battery-powered sensors and SwitchBot devices use BLE; a hub (e.g., SwitchBot Hub Mini or Shelly Plus) relays data to Wi-Fi [14]. Use a BLE–MQTT bridge on the reTerminal for local integration.
- **HTTP/REST** – Some lights and controllers provide HTTP APIs; integrate them using Node-RED's HTTP nodes or directly via your backend.

Software Tools

1. **Node-RED** – Suitable for rapid device integration and data flows. It offers built-in Modbus nodes and MQTT connectors and can run on the reTerminal. Node-RED is easy to learn, has a large library of function blocks and can be used to create dashboards; it is widely adopted in industrial IoT projects [18].

2. **Home Assistant** – Provides a flexible integration framework with built-in support for Modbus, MQTT, Zigbee and Z-Wave. It can run on the reTerminal and exposes a web-based UI. The Modbus integration supports multiple serial or TCP connections [17].
3. **Azure IoT and Time Series** – Use Azure IoT Hub to ingest telemetry from the reTerminal; store raw and aggregated data in Azure Data Explorer or Time Series Insights. This supports the daily/weekly/monthly energy and environmental aggregations needed for your dashboard.
4. **Data warehouse & analytics** – Use a SQL or time-series database to store aggregated metrics. Provide APIs for the dashboard to query daily totals, averages and trends.
5. **Data labeling for AI** – Start logging data from all sensors and devices. Use this to train the Environmental Control AI Copilot (described below). Label events such as temperature spikes, RH anomalies and energy peaks.

Environmental Control AI Copilot

Opportunity and Benefits

Researchers have demonstrated that AI-enabled environmental control systems can significantly reduce energy consumption in indoor agriculture. A Cornell University study found that integrating deep reinforcement learning with climate control reduced energy use by **around 25 %**, lowering energy required to grow lettuce from 9.5 kWh per kilogram to 6.42 kWh [19]. AI optimised light and ventilation schedules by reducing ventilation during light periods and increasing it during dark periods, balancing CO_2 levels and plant respiration [20]. This highlights the value of collecting granular data and using AI to optimize lighting, ventilation, dehumidification and cooling.

Implementation Suggestions

- **Advisory mode first** – Train models to detect correlations between PPFD, spectrum and environmental variables (temperature, RH, VPD), outdoor weather vs. HVAC energy, and group-level changes vs. hot/cold zones. Use daily aggregates and correlation coefficients to generate insights.
- **Use reinforcement learning for control** – After sufficient data collection and testing in simulation, implement an optional autopilot. Set guardrails (e.g., PPFD and VPD limits, maximum change rates) and require human approval for adjustments.
- **Integration** – Run AI analytics in the cloud using Azure Machine Learning or Python. Surface recommendations in the dashboard with confidence metrics and links to supporting charts. Provide an easy mechanism for farmers to accept or reject suggestions.

Opportunities & Recommendations

1. **Develop a library of compatible devices** – Create a curated list of lights, sensors, HVAC units and smart plugs known to work with Modbus, MQTT or 0-10 V. Include equipment like Shelly Plus 0-10 V controllers [3], SenseCAP CO_2 sensors [15], Swiss-sensor-based temperature/humidity meters [13], and energy-monitoring smart plugs [5]. This helps growers select devices with assured compatibility.

2. **Support multiple communication protocols** – The dashboard should interface with Modbus (RS-485/TCP), MQTT, BLE (via hub) and HTTP. Node-RED or Home Assistant can act as the edge integration layer, converting protocols and sending data to Azure.

3. **Automated device discovery** – Implement mDNS or MQTT discovery for future GreenReach devices. For third-party devices, maintain a registry and use scanning tools to identify unknown IP devices on the network. Use the wizard to assign them to rooms/zones.

4. **Unified energy monitoring strategy** – Combine CT-based branch meters with plug-level monitoring to provide both high-level and device-specific consumption data. Use the energy data to compute efficiency metrics and feed them to the AI copilot.

5. **Guided onboarding and health badges** – After setup, present a profile summary with badges indicating whether energy metering, scheduling and sensor coverage are complete. Suggest next steps (e.g., add outdoor weather or CO_2 sensors) to improve AI accuracy.

6. **Leverage low-code dashboards** – For the prototype, consider building the UI using Node-RED dashboards or an equivalent low-code framework. This allows quick iteration and helps validate the information architecture before investing in a custom front-end.

Conclusion

The Farm Profile wizard and associated features lay a strong foundation for a comprehensive indoor farm dashboard. Success will depend on adopting open communication protocols, choosing reliable sensors and controllers, and using low-code tools to integrate diverse devices quickly. With accurate environmental data and energy monitoring, the AI copilot can deliver actionable insights and reduce energy consumption. Implementing the recommendations above will ensure the dashboard represents the needs of indoor farms using both GreenReach and third-party equipment and provides a scalable path toward intelligent automation.

---

[1] [2] [7] [18] Why Node-RED is perfect for low-code development & dashboards
https://qbee.io/node-red-is-perfect-for-industrial-low-code-development/

[3] [4] [6] Shelly Plus 0-10V Dimmer
https://kb.shelly.cloud/knowledge-base/shelly-plus-0-10v-dimmer

[5] Wi-Fi Enabled Smart Plug with Energy Monitoring - Greenlite Lighting Corporation USA
https://www.greenliteusa.com/products/smart-plug-with-energy-monitoring/

[8] Monitoring: CT sensors, modbus meters and/or plugs? - Getting Started - OpenEnergyMonitor Community
https://community.openenergymonitor.org/t/monitoring-ct-sensors-modbus-meters-and-or-plugs/16926

[9] [10] [11] [12] Sensors for Agriculture and Environmental Monitoring for Indoor Ag Systems
https://blog.amphenol-sensors.com/industrial-blog/sensors-for-agriculture-and-environmental-monitoring-indoors

[13] [14] SwitchBot Meter | Smart Temperature & Humidity Monitor with IP65 Rating | SwitchBot US
https://us.switch-bot.com/products/switchbot-meter

[15] [16] SenseCAP SOLO CO2 5000 - NDIR CO2 Sensor - Seeed Studio
https://solution.seeedstudio.com/product/sensecap-solo-co2-5000-ndir-co2-sensor-supporting-modbus-rtu-rs485-and-sdi-12/

[17] Modbus - Home Assistant
https://www.home-assistant.io/integrations/modbus/

[19] [20] How AI can slash indoor farming energy use
https://www.agtechnavigator.com/Article/2024/09/10/How-AI-can-slash-indoor-farming-energy-use/