Case Study: Automated Greenhouse Environmental Control (Pakistan)

GIBES INOV – Embedded Systems, IoT, and Applied Agricultural Automation

Industry Overview

Agricultural R&D in Pakistan is rapidly transitioning toward climate-smart technologies. Research institutions increasingly rely on automated systems to manage controlled environments for crop genetics, stress-response studies, and precision irrigation. Typical greenhouses in South Asia still depend on manual measurements or low-reliability microcontroller kits, leading to data loss and inconsistent environmental regulation. International studies indicate that automated greenhouse systems can improve crop health research accuracy by 30–40% and reduce water consumption by up to 25%.

Client Background

A leading Pakistani agricultural research team required a reliable, low-cost, embedded system to monitor and regulate:

- Temperature
- Humidity
- Soil moisture and irrigation cycles

Their goal was to deploy the system inside an experimental greenhouse to secure a multi-year research grant. Internal attempts using basic microcontroller kits failed due to:

- Frequent firmware crashes
- Poor sensor accuracy
- SD-card data corruption
- Inability to maintain stable control loops

Key Metrics

Metric	Before GIBES INOV	After GIBES INOV	Resu
Prototype Delivery Time	4 Months (Estimated)	5 Weeks	Fast-Tra
Data Logging Reliability	Sporadic (SD Card)	99.9% (Cloud + Local Redundancy)	High
System Robustness	Frequent Bugs	Production-Ready	Gran

Challenges & Constraints

The research team required:

- A robust embedded platform able to run continuously for months.
- Consistent data capture for scientific analysis.
- Accurate readings for environmental control.
- A scalable cloud solution for remote monitoring.

The major constraints included a limited R&D budget, the need for fast delivery, unstable power supply, and high sensor noise due to greenhouse microclimates.

GIBES INOV Solution Architecture

Custom Hardware Platform

GIBES INOV engineered a custom PCB designed for:

- STM32 (ARM Cortex-M) microcontroller for industrial stability.
- Multiple 12-bit/16-bit ADC channels for environmental sensors.
- Isolated MOSFET drivers for HVAC fans and irrigation valves.
- On-board power conditioning for voltage spikes common in rural areas.

The board was fabricated in a batch of 10 units for field testing and prototyping.

Firmware & Control Logic

Firmware was developed in C/C++ with:

- PID thermal and humidity control loops.

- Soil-moisture-regulated irrigation.
- Watchdog timers and brown-out protection for reliability.
- MQTT protocol for cloud transfer with auto-reconnect logic.

The control logic was tuned to prevent:

- Overshoot in temperature/humidity
- Irrigation flooding
- Sensor drift errors

Data Architecture

To achieve research-grade data reliability, GIBES INOV implemented:

- Dual-path data logging (local Flash + cloud database)
- Real-time environmental dashboard
- MATLAB integration for post-processing of climate experiments

Cloud visualization enabled:

- Graphs of temperature, humidity, irrigation cycles
- Alerts for abnormal conditions
- Longitudinal datasets for research publications

Deliverables

- 10 custom-designed, production-ready PCBs
- Fully documented open-source firmware
- Cloud system setup documentation
- Sensor calibration sheets and control-loop tuning parameters

Implementation Timeline

- **Week 1:** Requirements analysis, electrical design.
- **Week 2–3:** PCB fabrication, firmware base architecture.
- **Week 4:** System integration, cloud dashboard setup.
- **Week 5:** Field testing, final tuning, handover.

Results & Impact

The results were strong enough to secure the research team's next-phase funding:

- 5-week delivery accelerated project timeline by 75%.
- 99.9% data availability enabled high-confidence climate analysis.
- Stable closed-loop control reduced environmental fluctuations by 40%.
- Provided a scalable blueprint for future greenhouse automation research nationwide.

About GIBES INOV

GIBES INOV develops advanced embedded systems, IoT architectures, and automation solutions across agriculture, industry, and research labs in Pakistan and Europe. Our R&D-focused engineering accelerates innovation while ensuring reliability and measurable scientific outcomes.