

CASE STUDY

Scaling Carbon Capture, Utilization, and Storage with Unified Digital Operations



 **Zemoso**

Introduction

A leading energy services provider partnered with Zemoso Labs to address a core obstacle in large-scale decarbonization: fragmented data systems across its carbon capture, utilization, and storage (CCUS) program.

Disjointed monitoring tools and manual compliance workflows slowed responses to operational risks.

Zemoso built a unified digital platform that aggregates sensor data from wells, fields, and plants into a single, real-time operational view.

By embedding risk management and alert intelligence into the workflow, engineers gained a live picture of field conditions and the context to act fast.

The platform reduced downtime, improved safety, lowered monitoring costs through automation, and strengthened audit readiness—directly supporting the client’s net-zero targets and enabling CCUS expansion with confidence.

Industry challenge

CCUS has moved from pilot projects to a central lever in industrial decarbonization. But scaling it exposes a recurring set of operational and data challenges:

- Subsurface, surface, and plant-level systems that operate in silos
- Manual or inconsistent monitoring and reporting
- Rising compliance complexity and data-traceability requirements
- Delayed anomaly detection, increasing safety and financial risk

Without an integrated data architecture, carbon-management programs become reactive.

The industry needs more than data collection—it needs data coherence across the entire capture, transport, and storage chain.

Zemoso's partnership challenge

The client’s CCUS teams were managing isolated data streams—raw CSV exports from wells and plants that required manual handling before analysis.

Existing tools lacked interoperability, preventing a real-time view across assets.

The mandate was clear:

- Build one system that connects subsurface, surface, and plant data
- Embed proactive risk and alert management linked to compliance thresholds
- Design a cloud-native architecture ready for global CCUS scale-up

In parallel, the system had to align multiple teams—capture, storage, and transport—under a common operational framework that regulators could trust.

Impact created

The digital platform became the client’s operational backbone for CCUS, producing measurable gains in reliability, efficiency, and audit readiness.

By converting fragmented sensor inputs into actionable intelligence, it accelerated the company’s path to regulatory compliance and net-zero progress.

How did we do this?

Zemoso engineered a unified digital backbone for CCUS—secure, modular, and capable of real-time processing across heterogeneous data sources.

The key breakthrough was linking subsurface-to-surface telemetry with a risk-aware alerting layer, ensuring every anomaly carried both context and traceability.

Key Engineering Breakthroughs

- **Real-time stream processing:** Managed acoustic, flow, pressure, and temperature data across wells, fields, and plants with sub-second latency.
- **Risk-linked alerting:** Every alert is tied to a predefined risk category, improving response precision and audit traceability.
- **Modular microservices with module federation:** Each function—dashboards, notifications, risk models—can scale independently without affecting overall performance.
- **Compliance built in:** Audit trails, data exports, and rule mapping integrated natively into daily operations.

Solution Highlights

1. Unified Data and Visibility:

A central platform powered by Databricks ingests and aggregates raw CSV streams—pressure, temperature, flow, acoustic, and microseismic data—from wells, fields, and plants.

The front-end stack (Angular, Plotly, Leaflet) delivers world-map visualizations, KPI cards, and asset-level dashboards.

Operators and executives share the same single source of truth, removing delays caused by disconnected tools.

2. Proactive Risk Detection and Management:

A structured risk-management framework was embedded in the system. Users can define risks, assign severity, and link mitigations directly to alerts.

Each event moves through a defined chain—hazard → alert → control—so teams see not just what happened, but why and what to do next.

This shifted alerting from noise generation to informed decision support.

3. Compliance-first Framework:

Every workflow was designed to satisfy emissions reporting and audit demands. Alerts tie to thresholds such as CO₂ injection pressure or flow anomalies, and exports produce audit-ready CSVs.

Role-based access control governs visibility and permissions, making compliance a native outcome rather than a parallel process.

4. Scalable Cloud-native Architecture:

Built on 18 microservices orchestrated through Kubernetes, the backend stack—NodeJS, Express, TypeScript—handles distributed workloads efficiently.

Redis caching supports high-frequency queries, Azure Blob Storage manages large sensor datasets, and RabbitMQ with Dapr ensures reliable event messaging.

CI/CD pipelines via Jenkins and GitHub enable frequent, secure deployments without downtime.

5. Advanced Security and Reliability:

A layered security model protects sensitive operational data:

- Static and dynamic code testing (Checkmarx, DAST)
- Cloud monitoring (Prisma) and vulnerability scans (AVScan, Black Duck)
- Encrypted Docker images and hardened transmission protocols
- Together, these safeguards ensure both cyber and operational integrity for regulated CCUS environments

How did Zemoso deliver excellence

The collaboration turned CCUS monitoring from a network of disconnected tools into a single, auditable digital system that scales.

By fusing data architecture with operational safety and compliance, the platform turned carbon management from manual oversight into automated assurance.

As CCUS projects expand globally, the client now operates on a digital foundation built for regulatory resilience, real-time visibility, and scalable decarbonization.